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CONTENTS

October, 1961

Papers

Page

Research and Civil Engineering Education
by Nathan M. Newmark 1

Research for Survival
by Arthur G. Trudeau 15

Research and the Professional Society
by Arthur T. Ippen 35

Atomic Power, A Failure in Engineering Responsibility
by Adolph J. Ackerman 43

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Journal of
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RESEARCH AND CIVIL ENGINEERING EDUCATION

By Nathan M. Newmark,[1] F. ASCE

SYNOPSIS

From a survey of research in civil engineering departments in colleges of the United States, it has been found that the level of support from all sources including the colleges themselves is, as of 1960, about $10,800,000 per year. This research program supports the full-time equivalent of nearly 500 professors and almost 700 graduate student assistants, corresponding to about 1400 students of the total number of 3600 graduate students enrolled in civil engineering.

A concentration of graduate study exists at the institutions having the largest research programs. Nevertheless there is not sufficient support for research to permit as many students as need research experience to have such experience as part of their educational background. It is estimated that additional support to the extent of 3 to 4 million dollars per year is required immediately, and that as much as 14 million dollars more per year will be required during the 1960's.

The recommendation is made that the American Society of Civil Engineers (ASCE) seek means of finding additional funds for university research, and that such research be kept as free as possible from control or restrictions on

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publications in order that the students, the faculty, the Society, and the profession can benefit most from the effort.

CHANGING CONCEPTS OF CIVIL ENGINEERING EDUCATION

Changes are taking place rapidly in civil engineering education. At the undergraduate level at most institutions there has been a greater emphasis on science and mathematics and less training in the routine of design. There has been an equally important change which has manifested itself in recent years by the rapid expansion of graduate study in civil engineering. For example, the total number of Ph.D. degrees awarded in civil engineering at the University of Illinois, Urbana, Ill., from the time of the establishment of the department, was only three in 1934, and reached 138 in June, 1960. It was half that number in 1953. The total number of master's degrees awarded through the same three periods was 144 through 1934, and 1222 through June, 1960. It was about 600 through 1952. This emphasis on graduate work is typical of the situation throughout the United States and has been accompanied by a growth in the magnitude of research programs at universities and colleges. As a matter of fact, it has become quite clear that a strong graduate program cannot exist without a strong research program. There is even some question whether a strong undergraduate instructional program can exist without a staff having an interest in and a continual contact with research. Certainly the undergraduate civil engineering educational program of the future will involve much more contact with research than it has in the past.

IMPORTANCE OF RESEARCH IN CIVIL ENGINEERING EDUCATION

There are four reasons why research is important in civil engineering education:

1. Research is important in the training of students, especially at the graduate level. As stated by L. V. Berkner,[2] graduate research must provide "the opportunity to do something creative and significant, or to solve some major engineering problem in a way that transcends existing practice. The objective of graduate research is to penetrate fully the existing status of applicable science and evaluate the potentialities of extensions of that science in an imaginative solution to the problem at hand. Thus the graduate must learn by research experience and discipline how to employ science to the end of application. In graduate research, inferences of science must be clearly mastered, exploited, and employed for engineering solutions." These remarks are also applicable, to a more limited extent, to undergraduate education in its changing concept, not so much because of the research which the student may do but because of the atmosphere in which he studies and works and because of his relationship to his instructors.

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[2] "The Role of Research in Engineering Education," by L. V. Berkner, presented at 68th Annual Meeting, ASEE, June, 1960.

2. Research is important in the development and retention of staff. Research experience and continual activity in research is as important in the development of an engineering teacher as practical experience. To some extent research experience takes the place of practical experience. However, it has the advantage of keeping the teacher acquainted with current and future developments rather than with the past. Teachers whose only outside activity has been in practice may easily become a decade out of date in their outlook unless they continue to have contact with practice. This time lag is magnified because of the fact that their students go into engineering work as much as 5 yr after they have had contact with the teacher.

The teacher who has no interest in the "why" as well as the "how" in his field is not usually a good teacher and is rarely a stimulating teacher. The bright young minds who should be attracted to civil engineering are discouraged by contact with teachers who are not alert, up-to-date, and enthusiastic about their field. Moreover, the brightest and ablest staff members can be attracted to careers in teaching by the opportunity to devote a good portion of their time to the independent study of the basic problems in their field of interest. The attractions of a university career are great to certain types of people. But more outstanding teachers are needed and ways must be found of inducing them to continue in university careers in spite of attractive opportunities in business or industry. From experience at several large universities, it has been found that opportunity for research helps to retain staff members even in the present-day competition for outstanding men.

3. Research is an important means of subsidizing graduate study. Most students cannot afford the lengthy period of graduate study required to obtain even an M.S. degree, and certainly not the doctorate. At the master's level, the 1 yr to 2 yr that are required may be a financial burden upon many young men, particularly those with family responsibilities. Stipends of some sort, including fellowships and research assistantships, are essential. It has been the experience of most schools that approximately 85% to 90% of all graduate students in engineering are subsidized in some manner. The figure is even higher for fields such as chemistry and physics. Research contracts and budgeted research allocations in the educational program are necessary for the employment of these young men on a part-time basis to enable them to continue their graduate study without too great a financial sacrifice.

4. Research is important to the profession. This is an obvious point. The development of the technical aspects of civil engineering is dependent on research and generally on that research which is done in universities. These technical developments find their way into practice and have an effect on all of engineering. This fact, of course, is the justification for the contract research programs which are the main support of research at most schools. Yet to the school and to the profession the other three items may be of equal importance and should not be overlooked.

CURRENT STATUS OF CIVIL ENGINEERING RESEARCH

In an attempt to obtain recent and accurate figures indicating the magnitude and type of research program carried on in various civil engineering departments and universities, a questionnaire was mailed to all accredited civil engineering departments in the United States during the fall of 1960. Replies

of some sort were received from 112 of the 136 schools, with complete replies from 97 institutions including all except three of the large or moderately large schools.

In Table 1, there is recorded a summary based on the final returns received, of the annual research effort in civil engineering. The amounts, in thousand dollar units of the research program, divided into categories of "basic," "applied," and "routine," are shown for several sources of support including industry and trade associations, technical societies and research councils, local and state government, federal government not including Department of Defense, and other sources such as endowed foundations, and so on. In addition, there is also indicated the extent of financial support given directly by the university or school concerned. These figures do not include overhead or indirect support whether from the university or elsewhere.

Some remarks are necessary with regard to the definitions of terms. In this context, "basic" refers to the idea of fundamental with respect to civil engineering. Some of the things that are regarded as basic in civil engineering

TABLE 1.—SUMMARY OF ANNUAL RESEARCH EFFORT IN CIVIL ENGINEERING[a]

Source of Support	Net Amounts in $1000			
	Basic	Applied	Routine	Total
Industry & Trade Assoc.	393	478	252	1123
Tech. Soc. & Res. Councils	194	85	---	279
Local & State Govt.	1031	1417	155	2603
Federal, Non Dept. of Defense	2141	707	21	2869
Dept. of Defense	1029	807	22	1858
Other	255	44	---	299
University	931	364	8	1303
Totals	5974	3902	458	10334

[a] Based on survey report from 97 universities.

research might be "applied" in some of the areas of science. The term "applied" means those aspects of work which have a direct relationship to a particular design problem or other type of problem in practice. These are usually research problems which have a less general applicability, and are usually of importance only in connection with civil engineering applications, but not ordinarily in other fields of engineering or science. Research leading to changes in design specifications, for example, would ordinarily be "applied."

The term "routine" involves the conduct of testing operations of a nature that is not really research. This may be the testing of concrete cylinders to determine their strength for construction projects, but may also include the conduct of even more complicated tests in which the university group do testing work only and have no part in the planning or in the interpretation of the results. Although there may be some ambiguity in the application of these terms, they appear to be well understood throughout the university community, and in general there is a fair agreement as to the designation that should be applied to particular efforts. In any case, the terms were applied by the individual reporting for the particular university, and are not the writer's designations for the research recorded.

The total research program reported by the 97 schools filling complete returns is $10,334,000, of which nearly 6 million dollars is basic research, nearly 4 million is applied, and almost half a million is routine testing. Replies from fifteen additional schools indicated that no research was being conducted. However, because four of these schools indicated that some personnel were being supported by research, it was estimated that a total amount of $45,000 was involved. For the remaining schools that did not reply to the questionnaire, an estimate was made that $403,000 of research was being conducted. These estimates were based on an interpretation of published statistical data including especially the "Engineering College Research Review—1959," prepared by the Engineering College Research Council of the American Society for Engineering Education (ASEE). Because these estimates could not be checked they are not included in the analyses given in Table 1 through 3, but

TABLE 2.—SOURCES OF RESEARCH SUPPORT

Source	Percent of Total
Industry and Trade Assoc.	11
Technical Societies and Research Councils	3
Local and State Govt.	25
Federal, Non Dept. of Defense	28
Dept. of Defense	18
Other	3
University	12

TABLE 3.—PERCENT OF RESEARCH EFFORT IN VARIOUS CATEGORIES

Source	Basic	Applied	Routine
Industry & Trade Assoc.	35	43	22
Tech. Soc. & Res. Councils	70	30	--
Local & State Govt.	40	54	6
Federal, Non Dept. of Defense	74	25	1
Dept. of Defense	56	43	1
Other	85	15	--
University	71	28	1
Total	58	38	4

they are taken into account in the overall summaries examined later in this paper.

The balance between basic and applied research is not an unhealthy one. In engineering research there should be some influence of application of the research program, but it should not be overwhelming. The amount of routine testing might be a source of concern. In some instances it is undertaken merely to find a means of support for research staff and students. In other instances it is undertaken because of certain pressures to which universities are subject. These pressures should be decreased rather than increased. Any steps that ASCE takes to develop research in universities should steer free of possible controls which might increase the amount of routine testing effort that is

conducted. This type of work has no helpful influence and may be even detrimental to the staff and students.

SOURCES OF SUPPORT OF RESEARCH

In Table 2, the proportions of the total amount of research supported by various sources is summarized. It appears that industry sponsors about one-ninth of the total research program in civil engineering, technical societies and research councils only 3%, and governmental agencies nearly three-fourths, with the federal government, other than the Department of Defense, accounting for the largest share, 28%. Other sources account for a relatively small proportion, 3%, and university sources support nearly one-eighth of the effort.

The percentage of the research effort in the categories of basic, applied, or routine is summarized in Table 3, for each category separately and for the total. For the total effort, 58% is basic, 38% is applied, and 4% is routine. However, for the research sponsored by industry, 35% is basic, 43% is applied,

TABLE 4.—TOTAL ENGINEERING RESEARCH AT UNIVERSITIES—1958 NSF SURVEY

Source	Amount, in $1000	Percent of Total
Industry	10,400	15
Federal, Non Dept. of Defense	9,200	13
Dept. of Defense	39,400	55
Other	1,400	2
University	10,500	15
Total	70,900[a]	100

[a] 57 percent is "basic" research.

and 22% is routine. This is the largest part of the research program which has routine aspects. The only other sources of support which involve any substantial amount of routine testing are local and state governmental agencies.

It is of some interest that the largest sources of funds for basic research are federal agencies outside of the Department of Defense. The proportion of the allotment from such agencies that can be considered as basic is 74%, whereas the basic research aspects of Department of Defense funds in civil engineering is only 56% and the proportion of basic research from the funds given by local and state governments is 40%.

Although the figures are not entirely comparable because they are for different years, it is of some interest to compare the magnitudes and percentages in Tables 1, 2 and 3 to those in the survey reported in Table 4. The data in Table 4 are taken from a 1958 National Science Foundation (NSF) survey.[3] The total amount of $70,900,000 is roughly seven times the amount of the current research program in civil engineering, and perhaps eight to nine times the civil engineering research effort in 1958. The percentages of the total support ob-

3 "Civil Engineering," September 1960, page 31.

tained from various sources are quite comparable to those shown in Table 2. The 57% listed as basic research is also close to the proportion shown in Table 3 of the overall effort, of 58%.

COMMENTS ON RESEARCH EFFORT

It is desirable at this point to make it clear that the summary of the research effort in civil engineering obtained from civil engineering departments may either underestimate or overestimate the actual research effort devoted to civil engineering. The possibility of overestimate lies in the fact that many of the research programs sponsored by Department of Defense agencies, and some of those sponsored by other groups, are outside of what is commonly conceived to be the field of civil engineering. The writer does not take this view. Civil engineering is any professional activity that the civil engineer feels is worth while. Programs which involve fundamental aspects of fatigue of metals, brittle fracture, and so on, are as much civil engineering as they are mechanical engineering, physics, or naval architecture.

On the other hand, the research effort in applied mechanics, sometimes conducted in other departments than civil engineering, is in many respects related to and in support of civil engineering. However, because of the fact that this research effort has little if any impact on civil engineering undergraduate and graduate education, it is included in this summary only where mechanics is a part of civil engineering and has a direct effect on civil engineering education. Possibly one of the most difficult problems related to the future development of civil engineering education is the fact that there is a separation between engineering mechanics and civil engineering in a number of institutions.

The relationship of research effort to graduate instruction leads to a concentration of research at those institutions which have strong graduate instructional programs in civil engineering. It must be understood that graduate instruction is an expensive matter involving not only buildings and equipment with large capital costs, but the most highly paid teachers and the necessity for large subsidies from research programs for payment of stipends to graduate students. Consequently, there is an apparent concentration of research effort at a small number of universities. This is illustrated in Table 5. The two universities reporting the largest research budgets account for one-sixth of the estimated total of research effort in Civil Engineering. The next three and the succeeding five account for nearly equal shares. That is, one half of all the research effort is conducted at the first ten schools. At the other extreme, only one-seventh of the total effort is carried on in 100 schools in the country.

The number of graduate students enrolled at the various schools is also shown in Table 5. These data were obtained from the questionnaire, and verified by reference to a survey[4] prepared by the U. S. Office of Education. There is an apparent concentration of graduate students at the universities with the largest research budgets, but the lower end of the list (in terms of magnitude of research budget) contains several schools with large evening enrollments and very small research budgets. Nevertheless, 25% of all the graduate stu-

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4 "Engineering Enrollments and Degrees, 1959," by W. E. Tolliver and H. H. Armsby, Circ. No. 617, U. S. Dept. of Health, Education, and Welfare, Office of Education, 1960.

dents, and 50% of all the research effort, are found in only ten schools; and nearly half of the graduate students and over three-fourths of the research effort at the "top" twenty-five schools.

An interesting measure is given by the statistic reported in the table showing the average amount of research per graduate student enrolled in each of several groups of schools. These values range from a low of $900 to $1100 for the lowest 100 schools, to a high of $6,700 for three of the top five schools. The overall average for the United States is $3000.

There can be valid questions raised concerning the adequacy of graduate work in institutions at which the research effort is extremely low as measured either in these terms or in absolute magnitude. This emphasizes the need for additional funds for civil engineering research.

TABLE 5.—CONCENTRATION OF RESEARCH EFFORT AT UNIVERSITIES

Order of school in magnitude of Research Budget	Group Quantities				Cumulative Amounts		
	Research total		No. grad students	Research dollars per student	Research Budget $1000	Percent of total	
	$1000	percent of total				Research	Graduate student
1,2	1824	16.9	360	5100	1824	17	10
3,4,5	1753	16.3	262	6700	3577	33	17
6-10	1755	16.3	283	6200	5332	50	25
11-15	1252	11.6	286	4400	6584	61	33
16-20	1017	9.4	313	3300	7601	71	41
21-25	676	6.3	192	3500	8277	77	47
26-35	940	8.7	393	2400	9217	86	58
36-65	930	8.6	879	1100	10147	94	82
66-97	187	1.7	215	900	10334	96	88
Remainder	448[a]	4.2	454	1000	10782	100	100
Total	10782	100.0	3637	3000			

[a] Estimate

There are some interesting aspects of the staff support and the student subsidies implied by the data concerning research programs. The questionnaire contained items asking for the number of full-time equivalent senior permanent staff members of professorial rank, and the number of student research assistants, also on a full-time equivalent basis, who receive stipends from research funds. This does not include the relatively small number of students and staff members who work on research, but without stipend. For all of the schools reporting, the total number of senior staff and assistants, on a full-time equivalent basis, bears a nearly constant ratio to the total magnitude of research effort. Although there are some minor variations in this ratio, it is close to $9,000 per man. This is shown in Table 6. There is also shown in Table 6 the number of senior staff, the number of full-time assistants, the total personnel, and the magnitude of the research effort.

For the five schools with the largest budgets (the schools carrying the greatest reported proportion of research effort), the number of senior staff members and the number of assistants, both on a full-time equivalent (FTE) basis, are nearly equal; the ratio of FTE students per FTE staff member being

1.2. For fifteen schools with intermediate research budgets, the ratio of students to staff is approximately two to one. The proportion of students to staff is less for the schools with the smallest research budgets, being also 1.2 to one.

The cost of conducting research at universities is indicated best, perhaps, by the amount spent per full time senior staff member. These data summarized in Table 6 range from $19,700 for the "top" five schools, to a high of $25,700 for the intermediate group, down to a low of $12,500 for the "bottom" thirty schools where, presumably, salaries are lower.

These figures are consistent with the fact that the direct expenses of research effort at universities appear to be of the order of $20,000 to $25,000 per full-time senior technical man engaged in the program. This includes the man's salary plus the support which he requires to carry on his work. This figure will undoubtedly increase with increase in salaries contemplated in the

TABLE 6.—FULL-TIME EQUIVALENT STAFF AND STUDENT ASSISTANTS SUPPORTED BY RESEARCH FUNDS

Order of school in magnitude of Research Budget	Number of full-time equiv.			No. FTE assistants per FTE staff	Mag. Res. Budget in $1000	Research Cost per Full Time Man, Dollars	
	Staff	Assistants	Total			Staff	Total
1-5	184	221	405	1.20	3577	19,700	8,800
6-20	171	234	405	1.37	4024	23,600	9,900
21-35	63	122	185	1.94	1616	25,700	8,700
36-65	55	83	138	1.51	930	16,900	6,700
66-97	15	18	33	1.20	187	12,500	5,700
Totals	488	678	1166	1.39	10334	21,200	8,900

next few years. There are, of course, additional costs involved in the research program. These indirect costs are not reflected in the totals described here which involve only the productive technical effort. However, an additional amount per full-time equivalent senior staff member of the order of $10,000 may be required for the various overhead costs including purchase of equipment, and so forth, which are actual costs that must be borne by the institution, or in some other way, for the research program to be productive. One might estimate required support for research on the basis of roughly $30,000 per full-time equivalent senior staff member, and that for each full-time staff member there is the equivalent of 1.2 to 1.5 full-time student assistants, or in effect, 2.5 to 3 actual assistants (on a half-time basis) associated with the research program.

RESEARCH COUNCILS

In recent years there have been a number of research groups established to assist in developing support for and in supervising the conduct of research in several areas in civil engineering. Among these are the Research Council

on Riveted and Bolted Structural Joints, the Reinforced Concrete Research Council, the Column Research Council and, to some extent in civil engineering, the Welding Research Council, which antedates the other groups. These operate in slightly different ways but in general all the groups have relatively small budgets. Nevertheless they influence the contribution of funds from other sources beyond the support which they develop directly.

For example, the Research Council on Riveted and Bolted Structural Joints has a budget of the order of $25,000 a year of funds contributed directly through the Council, but has stimulated additional funds, primarily from state highway departments, ranging from $10,000 up to $40,000 per year.

The Reinforced Concrete Research Council (RCRC) has in its own funds a budget ranging from $12,000 to $21,000, with a special additional allocation of approximately $15,000 per year for a project on the behavior of reinforced concrete floor slabs for buildings. It has stimulated additional funds, however, of a magnitude difficult to assess because the additional funds might have been made available even without the RCRC effort. However, the additional effort has been variously estimated to be $20,000 to $40,000 per year during the period 1952-1960.

In the tabulations contained herein the funds have been listed in the categories in which they enter directly. Only the direct contributions of the research councils have been listed, and the contributory support from groups such as state highway departments or the NSF has been listed under the heading pertaining to those agencies.

It is all too often true that in research councils made up, in large part, of men from practice there is a natural tendency to de-emphasize basic research and to tend toward the more routine aspects of applied research. Part of this situation has been associated with the difficulty of raising funds for basic research, and the necessity for "selling" the research effort on the basis of the practical benefits that might accrue to those contributing funds to the activities of the research councils. Nevertheless, the NSF, the Office of Naval Research, and a number of other government agencies have sponsored research without the type of control exerted by the research councils, and the results have been most encouraging in their benefit both to the profession and to the research worker.

On the other hand the research councils mentioned have made possible a great deal of work in civil engineering of a fundamental nature, and their activities would be sorely missed if they were to stop their efforts entirely. The writer suggests, however, that the activities of research councils be considered from the point of view of: (a) giving general advice and suggestions; (b) raising funds; and (c) allocation of continuing funds without control to outstanding research groups or outstanding research individuals. The exercise of control over the research programs, the approval of publications resulting from the research, and similar details essentially usurp the prerogatives of the research man and hamper the research effort.

SUGGESTIONS AND RECOMMENDATIONS

It has already been implied that the primary types of assistance that university research effort requires are additional funds, the allocation of these funds on a reasonable basis, and advice and suggestions, rather than control,

from people in practice. It may be desirable to consider one additional aspect, namely a follow-up or assistance by professional groups such as technical societies and research councils in making the results of research available to the practicing engineer. This might sometimes be a function that should be conducted by the research man himself. However, it is better in the long run for the research man to publish his results freely and independently, and for the published results then to be used by the various professional groups, after discussion, in the development of design procedures and specifications. In contrast to the approval of publication of research results, it makes a good deal of sense to require approval from a professional group or a research council before a recommended specification is promulgated, even by a research man.

The greatest needs in research in civil engineering are unrestricted and uncontrolled continuing funds for research effort, and freedom of publication of the results without the approval of sponsors or donors. It is only with research of this type that schools can meet their requirements for the effective development of both undergraduate and graduate education, that they can retain the best and most promising staff members, and that they can contribute those fundamental aspects of knowledge necessary to the development of the profession.

Engineers in general are wary of federal control of activities ranging from school programs to voting rights. It would not appear to be necessary to argue that similar controls exercised by any group may hamper the development of individual research programs. This has been made clear in the fundamental sciences. Why it is not generally accepted in engineering is a question that needs further study. Possibly it is because in the field of civil engineering, research is a relatively new type of effort. It is not well understood by practicing engineers. There is not yet a general acceptance of the fact that the research man is pursuing an activity for which he has a unique training, and that design experience or even general all-around good common sense does not necessarily substitute for this training and aptitude. In other words, the research man is better qualified to direct, control, and do research than the practicing engineer.

This, then, is the basis for the writer's suggestion that additional support for research be to as great an extent as possible free of controls or restrictions, and that the results of such research be available for publication by the by the research worker, whether the results are agreed with or disagreed with by members of the profession. Furthermore, the support of research should be primarily directed toward the men doing the research, based on their demonstrated competence and the competence of those whom they are able to bring in association with themselves in their programs. Research needs a fertile atmosphere in which to grow.

With regard to the funds required, one can make a reasonably good estimate based on the number of graduate students in the civil engineering curriculum. During the 1959-1960 school year the number of graduate students in civil engineering[4] was reported as 3637, of whom 505 were working toward the doctorate. Considering past rates of growth, one can expect this number to double by 1968-1969. If, as in the past, 85% to 90% of the students are to be subsidized, taking into account other sources of support as at present, approximately 50% of them will have to be subsidized by research funds as assistants on research programs. This means approximately 1800 students in 1961 and

double this number by 1971. One-half of this number, or 900, will be the full-time equivalent number of students that need subsidy now. The figure will increase to 1800 by 1971. This estimate should be compared with the number in Table 6, of 678 full-time equivalent students who are now subsidized by research funds.

In other words, a one-third increase in research support is needed in 1961 to adequately support research and graduate instructional programs in civil engineering departments in American universities. A further doubling will be required by 1971. This means that approximately $3,500,000 of additional research funds are needed annually in civil engineering, without curtailing any of the present support, and a total of $14,000,000 per year additional may be required in ten years. The needs are very great. Yet without these additional funds graduate students of the future will not have the kind of educational experience that they require.

As a matter of fact, even with the additional support suggested, the amount of time available for research on the part of faculty members in civil engineering will only begin to approach that available now in electrical engineering and chemical engineering, and the magnitude of the support per graduate student will become more nearly comparable to that in those areas.

In addition to this continual requirement of funds on an annual recurring basis to support research activity, there is an urgent need for buildings and facilities for civil engineering departments in the United States, which are in general more poorly housed than other departments. In many state universities, for example, even though adequate support for salaries has been achieved, completely inadequate facilities for research and instruction are available. To supply the space and facilities required for research and for graduate education in civil engineering will require approximately $10,000,000 per year for the next 10 yr, (to 1971), in addition to the money to support research personnel and students.

It is not the purpose of this paper to suggest how this money can be raised. It is an obligation of the Society and the profession, as well as of those industries associated with civil engineering, to find a means of supporting required research activity in civil engineering at colleges to an extent commensurate with the requirements for the education of the civil engineers of the future, and a means of acquiring and retaining of adequate staff members to teach these engineers.

CONCLUSIONS

The following conclusions are drawn from the survey and the analysis of the results:

1. Research has an important bearing on graduate education and, through the training of teachers, on undergraduate education also. High quality graduate instruction requires greater research support.
2. Industry and technical societies are not carrying their share in the support of civil engineering research. Moreover, the type of research presently sponsored by industry tends too much toward routine testing.
3. There is immediate need for 3 to 4 million dollars per year of additional research support at universities and colleges. This need will be higher if federal support of research should diminish in any respect.

4. To support projected increases in graduate enrollment, the additional needs for research may be as much as 14 million dollars per year in the next decade, assuming that federal and local governmental support remains constant.

5. There are additional and substantial needs for buildings and equipment to enable university research to be carried on properly.

6. ASCE can help most effectively by finding means of raising money for research, and by striving to keep additional support as free as possible from restriction or control of publication, so that the work done will be of the greatest value to the profession and to the students and staff of the schools that train civil engineers.

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RESEARCH FOR SURVIVAL[a]

By Arthur G. Trudeau[1]

SYNOPSIS

In face of the growing Soviet military threat and in an era of revolutionary progress in science and technology, a modern Army must be a changing Army. It must have the best in weapons and equipment that money and human skill can put together. In this business of research and development, the miracles of yesterday are fast becoming the relics of today.

Army Research and Development, to prepare for a future as awesome as it is near, is maximizing the use of today's great scientific discoveries and continually pressing for more progress in basic research. Basic research is the key to a future, dynamic technology.

The Army's contribution to basic research is now about $50,000,000 a year. The fields of interest that have seen the greatest advances are metallurgy, electronics, and new energy sources.

Basic research feeds the insatiable appetite of applied research and development; the other part of the Army's Research and Development (R and D) Program, in which the effort is concentrated in the classic fields of military endeavor—in improving firepower, communications, and mobility.

In the area of firepower, nuclear weapons and guided missiles are receiving wide attention, but are not the only novel weapons in the modern arsenal. Progress is also being made in improving tube artillery and light infantry weapons.

In the field of communications, the Army is perfecting devices to increase its command and control capability. It is also sharpening its ability to acquire target information and to maintain constant surveillance of the battlefield.

Note.—Discussion open until March 1, 1962. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. This paper is part of the copyrighted Journal of the Professional Practice Division, Proceedings of the American Society of Civil Engineers, Vol. 87, No. PP 2, October, 1961.

[a] Presented at the October, 1960 ASCE Convention in Boston, Mass.

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Mobility is the third vital field for R and D effort and the area in which the Army has the greatest need for progress. On the ground, commercial earth-moving and heavy construction equipment promise to provide ground combat forces true off-road mobility. New tanks and armored personnel carriers, now under development, will increase the striking power of the Army.

Through a ground mobility research program, the Army is seeking to isolate the primary factors influencing soil trafficability and determine their over-all influence on terrain and military operations. Present studies focus on such problems as how the weight, driving, turning, and stopping forces of a ground vehicle are transmitted to the supporting soil by various configurations of running gear.

Other developments in the fields of military bridging and construction are improving ground mobility. Among the most promising projects are the highly mobile floating assault bridge-ferry and the multi-purpose tractor.

In efforts to maintain its speed of movement, the Army is not overlooking the need for continuous logistical support. New projects in the logistical field include an overland petroleum distribution system over-the-beach equipment and a submerged terminal and submarine pipeline system.

Still, for better battlefield mobility, the Army is concentrating on the air—on aircraft of revolutionary design that fly just above "the nap of the earth" and have the take-off and landing characteristics of the helicopter with the advantages of the fixed-wing aircraft in forward flight.

Locked as the Free World is in vital competition with the Communists, there can be no doubt in the minds of all thinking Americans today as to why this nation must have the best possible weapons and equipment in all the Armed Forces. Without a doubt, the ability of the United States to maintain a qualitative weapon superiority over the Soviets may mean the survival of Western Civilization in years to come.

The Soviets picture mighty military power capable of attacking under the shield of an all-out nuclear offensive, and every success they achieve technologically sharpens the edge of the weapons race and enhances the effectiveness of their related means of conflict—political, sociological, psychological, and economic.

There is a real sense of urgency in military research and development today because the present era of revolutionary change is more rapid and meaningful than in any period during the last 500 yr. Hardly a field in the physical or social sciences is not changing significantly now—and changing rapidly.

What better example exists than the classic field of surveying. Army engineers wrestled for more than a decade with survey problems, using the slide rule, transit, level, rod, and tape in Alaska and the great Pacific Northwest—using instruments first developed by the early Egyptians. Except for product improvement, these instruments have withstood the test of the centuries. But, in less than two decades, modern science has produced such tremendous breakthroughs in electronics and photogrammetry that surveys are now made in ways that just a few years ago were viewed as revolutionary. The new electronic equipment for mapping and surveying, such as SHORAN, LORAC, the TELLUROMETER, and the airborne profile recorder are typical illustrations.

These electronic devices are improving our accuracies, to better than one part in 100,000, in measuring distances. Computers to reduce and process the raw survey data more rapidly than ever before are in existence, and the old "slip-stick" definitely takes a back seat when a data computer is around.

If American technology is to continue to accelerate at this pace, and it must to outperform the Communists, greater emphasis must be placed on basic research for new scientific knowledge and on applied research and development for new hardware items. Our national ability to provide adequate defense in the late 1960's and beyond will be determined by the military research and development effort this country is willing to support today.

It is the mission of military research and development not only to maintain this nation's present world-wide technological lead in weapons and equipment, but to replace existing material by improved or entirely new models as rapidly as possible. If ever its military forces and weapons for control of the air, sea, and land become inadequate or obsolete, the Free World well could fail in its earnest efforts to deter war and advance the cause of international peace and progress.

There was a time when the Army could develop and produce a weapon or a piece of equipment and use it until the day it wore out. Today that era is but a memory. The implications of modern technology, exploding on all fronts and revolutionizing man's concepts of war, are truly fantastic.

Although the horse and the lance remained a major weapon system in the world armies for 2000 yr, it is doubtful if the tank and the manned combat airplane, as known today (1961), will last 100 yr.

All the Armed Forces struggle with this problem today (1961). In July 1960, on Independence Day, the United States Army gave up its last antiaircraft gun, and today not a single one is operational in the whole North American air defense system.

Less than 7 yr ago, following the Korean armistice, 1,000 of those guns, 90's, 120's, and sky-sweeping 75's, girded our continental defense against foreign attack.

Through two wars and a quarter century of time, they were a main reliance. Today, they are an anachronism in a missile age when NIKE missiles ring our great centers of population and industrial power; at a time when we labor unceasingly to perfect our NIKE ZEUS missile to protect against the Communist threat of a nuclear hailstorm hurled through space.

For this reason, a Modern Army must be a quick-change artist in this fabulous age of science and technology.

Continual advances in radar, in electronic memory and computation devices, in television, in new power sources, in servo-mechanisms, and advances in a score of other fields are resulting in an ever-increasing number of new devices to solve many of the serious, complex problems currently facing the military. These problems are chiefly in the areas of mobility and target acquisition. Nuclear weapons have increased the need for greater mobility, far beyond what has been achieved today, and doubled the requirements for more accurate and speedy information. They have also accented the need for careful scientific assessment of targets before attack and immediate analysis of the resultant destruction. All of these new problems demand research and development of the highest order.

Science and technology can produce today just about anything that is needed, provided the needs are clearly spelled out and the implementing funds are available.

If yesterday's miracles are today's relics, what an age tomorrow will be, with science as the guide. The vision and the determination must exist from the grass roots to the policy level to push science and its related technology forward from the base of present achievements.

Army Research and Development is maximizing the great scientific discoveries of today and continually pressing for more progress in all fields, seeking further scientific breakthroughs basic to maintaining the new Modern Army of vastly improved power, range, and mobility.

This R and D program supports extensive investigations into basic research as well as into applied research and development. Its scope is as broad as man's imagination, for the Army's primary interest is in man, the soldier, and what it takes to sustain him in an environment more hostile today than ever before in all history. The Office, Chief of Research and Development, in monitoring this program, directs the efforts of approximately 40,000 civilian-military scientists, engineers, and supporting personnel who are concerned with some 400 projects and over 2,600 tasks. Today, Army funding for research and development requires more than $1,000,000,000 annually.

The extent of Army efforts in basic research—to penetrate the ever-shifting boundaries of science—is measured in terms of some 2,600 projects underway at more than 550 laboratories, universities, industries, and 80 Army and other government installations. A small part of this research is conducted overseas in Japan and in 14 countries in Europe. The present price tag on basic research is approximately $50,000,000 a year.

There are many in and out of uniform today who fail fully to appreciate the military's keen interest and support of basic research, thinking this to be only the job of industry, of universities, and of scientific foundations. This is not the case—basic research today is fast becoming a widespread national responsibility—everybody's business.

Such men of little vision, who do not see the critical importance of basic research, should be reminded of that delightful story of Michael Faraday, the renowned 19th century English physicist, and William Gladstone, one of the greatest English Prime Ministers.

In an age of great scientific discovery like today's, Gladstone visited Faraday in his laboratory to witness the celebrated experiment of electromagnetic induction—the simple experiment that has since revolutionized the world. Apparently, Gladstone with all his greatness had no appreciation of the practical uses of a moving wire in a magnetic field generating electricity, and after watching the deflection of the galvanometer needle, asked Faraday what possible use could come of it. Faraday's answer was incisive and meaningful then and now: "Why, Mr. Prime Minister," he said, "you will soon be able to tax it!"

Today, basic research not only holds forth great promise of increasing our national prosperity, reshaping the very pattern of our lives, but it promises to give the military truly revolutionary improvements in the crucial fields of firepower, communications, and mobility.

The weapons and equipment of the past, and even of the present, provide no solutions for the future.

Happily, both the Wriston Commission and the President's Science Advisory Committee continue to stress the need to expand our national effort in basic research. The Army is continuing to get modest increases in the monies allotted for its research, and a fair segment of American industry is con-

sciously expanding its effort in this critical area. Together, the Army-Industry Team must encourage this trend. Government, alone, cannot be responsible for, or do, the whole job in basic research. It cannot assume the entire cost of basic research in this country, now running about $1,000,000,000 a year. For the maximum in dynamic and realistic support, America must look to private enterprise, to industry, to educational institutions, and to scientific foundations for their contributions.

Engineering and military imagination have outstripped existing materials and surpassed the state-of-the-art in power sources. Through new advances in the science of materials research the Army expects to cut through conventional barriers and attain, for instance, the truly revolutionary improvement that is required in mobility. The progress, here, is dependent on the solution of crucial materials and energy problems.

The lack of new and unique materials today is perhaps the most important single factor holding up the development of true air vehicles that will fly just above the "nap of the earth," permitting the combat soldier of tomorrow to overcome terrain obstacles, such as mud, swamps, ravines, rivers, and forests. This type of vehicle will have the take-off and landing characteristics of the helicopter, coupled with the advantages of the fixed-wing aircraft in forward flight and will be able to fly fast or slow and quietly just above the battlefield.

The most pressing research and development projects are not in the field of development, but in research in finding the new materials that can make creation of advanced military devices possible. The unprecedented demands for new materials in this area are staggering; materials, for example, that can withstand conditions of extreme heat and pressure in the order of 500,000 psi and 2,000°C. All the Armed Forces share the need, and are working jointly in this area on a variety of approaches in plastics, in ceramics, in polymers, and in metals spending several hundred million dollars a year.

It is important to point out that metallurgy is a field that has seen tremendous advances in the last 10 yr and can be expected to surge beyond the boundaries of imagination in the next few. For example, it is estimated that within the next decade there will be beryllium alloys with the strength of steel, but 1/4 the weight. Shortly thereafter will come plastics and ceramics with the same strength-weight characteristics. New steels, with vastly improved characteristics, are in sight now.

Other metals such as molybdenum, tantalum, and niobium are being developed to withstand ultra high temperatures. These, and the high-strength metals, will have a profound effect on the civil engineering field and speed the advance of missiles, vehicles, and electronic devices.

Research efforts are also underway to bridge the gap between materials and solid state physics. Rich dividends, here, will permit the chain-linking of large molecules so that materials with properties hardly now imaginable can be created at order. Instead of having to work with materials on hand, the materials needed can be created out of atoms and molecules.

These and other materials research-sparked developments will redound to the benefit of our civilian industry and commerce as well as to the military, providing greater utilization of energy, increased measures of reliability, and more efficient space accommodations.

Electronics is another field that has seen a quantum jump in the last 10 yr. Basic research already has led to the technique of microminiaturization of electronic components. A cubic foot of space that only yesterday held 7,000

parts, now holds 350,000; and even this figure can be increased by a factor of ten in certain fuse applications. Using solid circuit techniques, even this is only a beginning. Other marvels in the electronic field are the ruby maser, the tunnel diode, and the parametric amplifier promising to increase tenfold the sensitivity and range of many Army electronic systems. And now, the LASER and IRASER are in sight.

To achieve true mobility in the air or on the ground—with almost noiseless operation, basic research must quicken its search for new energy sources. Efforts must be doubled to achieve new engines at less cost, with more economy, of less size and weight, and most important, with higher performance ratings under all kinds of conditions. Every new avenue that shows promise in the power spectrum, from today's gas turbine to tomorrow's fuel cell, from the magnetohydrodynamic generator to the solar cell, and in a future as awesome as it is near, nuclear power sources must be investigated.

Of these, the fuel cell now seems the most promising for the 1970's.

The fuel cell is an electrochemical device that produces electrical energy by direct chemical reaction. It has all the features of a battery except that the reactants, oxygen and some companion fuel like hydrogen, are supplied continuously; the products, carbon dioxide and water vapor, are removed continuously.

There are several commanding reasons for military interest in this cell. Significant is its potentially high efficiency compared with that of a gasoline or diesel motor, about 60% to 80% compared with 25% to 30%. This means more efficient utilization of fuel with substantial reduction in the logistical load. The fuel cell has no internal moving parts, no pistons, crankshaft, transmission, and the like; this means reduced maintenance. Of additional importance is the fact that fuel cells operate with an absence of noise or smoke, and generally without excessive heat. They are, therefore, harder to detect by the enemy on or above the battlefield.

Although the fuel cell promises some reduction in our supply requirements for fuels, in itself, the fuel cell is not the complete solution to our age-old logistics problem. One possible solution, in the 1970's, lies in the integration of the fuel cell, or groups of cells, with the nuclear reactor.

In this concept, a stationary nuclear-powered generation plant, much like a filling station, would furnish hydrogen and oxygen as fuels. Viewed in this light, the problem of providing propulsion fuel is reduced to the task of converting the energy from a nuclear plant to a form that can be conveniently dispensed and utilized in vehicles of numerous types.

The optimum form, an integrated fuel-power system as an integral part of a vehicle, is speculative. Unfortunately, the extent to which nuclear plants can be miniaturized appears to be limited, and the cost of reactors is still too high. Yet, the optimum might be approached in the development of a nuclear-powered, cross-country vehicle comparable to the overland train as a mobile supply point.

The several cars of the train would be equipped to manufacture certain chemicals, perhaps ammonia or hydrazine, from water and air and liquify it for convenient storage and handling. The heat and power for the process equipment would be provided by the nuclear plant which would also propel the train. The ammonia or hydrazine, in turn, would be furnished from this mobile service station to combat vehicles equipped with fuel-cell propulsion engines or to stationary fuel cells providing electrical power for other appli-

cations. Such nuclear-powered energy depots could manufacture versatile chemical fuel locally within a combat theater and transport it near or to the place of use. Such a unit could develop, within itself, the equivalent of 500,000 gal of gasoline per day. With POL constituting 40% of the Army's tonnage, the significance of such a development is apparent.

These advances illustrate, moreover, the kind of basic research effort that is necessary to feed the insatiable appetite of applied research and development, for without new knowledge, without new science, applied research and development is limited to product improvement. Product improvement, important as it is, will not put America out in front where she belongs, or keep her there.

The general areas of interest in the Army's applied research and development effort are the classic fields of military endeavor—firepower, communications, and mobility. Any Army must be able to move, shoot, and communicate any time, any place, under any conditions, and better than any potential enemy.

First, the firepower area.

Nuclear weapons have revolutionized firepower; missiles have boosted the post ranges of delivery and tremendously increased the impact power.

Tube artillery is under constant improvement as it still retains a vital importance for close-support and for delivery of conventional fires continuously and under any weather conditions.

Many types of improved guided missiles and rockets are under development to supplement or replace those that are now available. Among these are SERGEANT and PERSHING, both long-range, surface-to-surface missiles being developed to fire at ground targets. In the shorter ranges, LACROSSE has enhanced the reliability and accuracy of fire delivery. This highly accurate guided missile provides all-weather, close tactical support for the front-line soldier in conjunction with tube artillery.

To meet the Army's important mission in air defense, both a shoulder-fired missile, called REDEYE, for individual use of the combat soldier against attacking aircraft, and the amazingly effective HAWK missile, for use by field units against low flying aerial targets, are under development.

For a time firepower completely outstripped communications and mobility. But that picture is changing, particularly in the field of communications.

Advances in communications equipment have enabled the Army to increase its command and control capabilities to the degree now required by mobility and dispersion. In the electronics area, a wide variety of sensors, radar, automatic cameras, and infrared, seismic devices are being studied and adapted for drone use.

Figs. 1 to 5 illustrate some of our latest Army developments in the firepower and communications areas.

Fig. 1 depicts the DAVY CROCKETT, the Army's new battle group atomic delivery system. This revolutionary weapon is essentially a recoilless rifle and capable of delivering a powerful punch with either a high explosive or a nuclear warhead. Its ground mobility is excellent and it can be airlifted into action by helicopter.

LACROSSE, shown in Fig. 2, is a close-support guided missile of extreme accuracy. It is highly mobile, and it can be fired from a launcher mounted on a standard truck. It can also be carried by a helicopter.

FIG. 1.—DAVY CROCKETT

FIG. 2.—LACROSSE

The amazing air defense weapon "the bullet with the brain," pictured in Fig. 3, is called HAWK. HAWK provides a low-level air defense capability and is the counterpart of the NIKE HERCULES, now on site guarding the great industrial centers of America. It has destroyed F-80 drones at low altitudes. Recently HAWK has intercepted targets below 100 ft and up to 50,000 ft in altitude.

Also, HAWK is the antiaircraft missile that recently intercepted and destroyed HONEST JOHN, another ballistic missile. That amazing "bullet-hits-

FIG. 3.—HAWK

bullet" demonstration took place at the White Sands Missile Range in January, 1960, and the intercept is shown in Fig. 4.

Last August, the Army repeated this "bullet-hits-bullet" (or really "missile-hits-missile") demonstration, using a new improved NIKE HERCULES against a much faster target—another HERCULES.

Certainly such missile-against-missile feats are further proof of the high-speed intercept principle that the Army is exploiting in development of NIKE ZEUS, which the Army judges to be the most important contribution in the future for the defense of the United States against enemy ICBM's.

Fig. 5 shows the Army's newest drone system the SD-5. This surveillance drone with a subsonic speed is JATO-boosted into flight and radio controlled. Its sensory compartment accommodates photo transmission systems, infrared, radar, or other new electronic devices that transmit or bring back data. It

will have a data link system to transmit the output of each sensor to a ground station. The SD-5 is powered with a turbojet engine and is a member of a family of drone systems designed to provide the Army with an all-weather, surveillance capability. It is recovered by its own parachute and after refueling, it is ready to be used again.

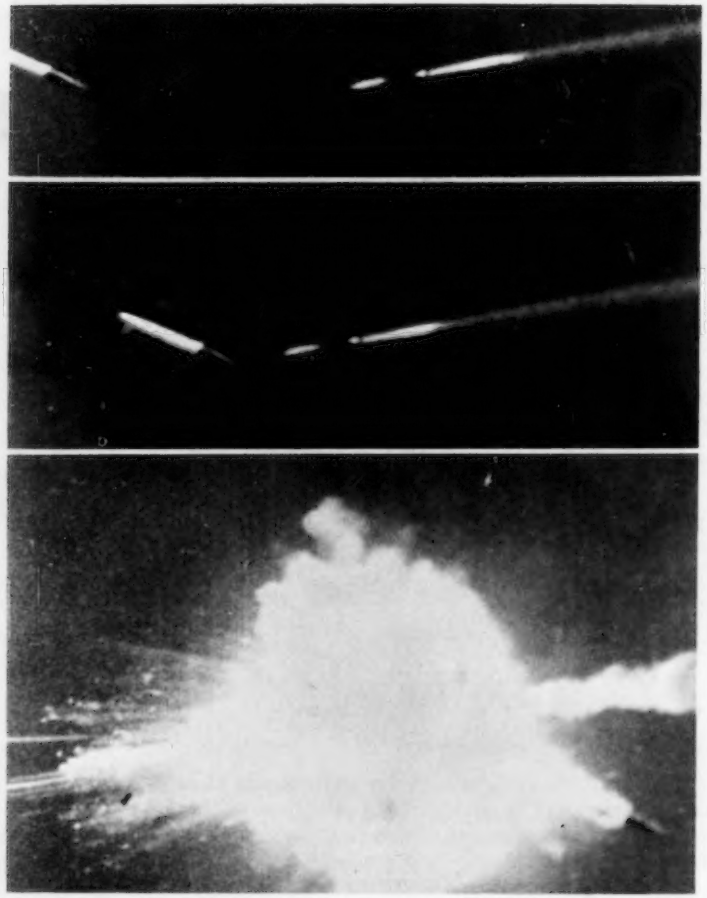

FIG. 4.—HAWK VERSUS HONEST JOHN. HONEST JOHN MOVING FROM LEFT TO RIGHT, HAWK MOVING FROM RIGHT TO LEFT

Within the framework of future possible conflicts—whether engaged in all-out nuclear war or in putting down aggression with conventional weapons, Army combat troops must react faster, cover more ground, protect larger areas, disperse, and regroup faster than ever before. At the heart of this mobility

problem is one simple fact; the greater the speed of movement over all types of terrain, the greater the chances of tactical success.

The "GOER" type of equipment used in commercial earth-moving and heavy construction work, where large wheels and tires give true off-road mobility, promises to improve present ground mobility. The "GOER" is now under development to provide the logistic support necessary to mobile and dispersed combat operations.

Also, new tanks and armored personnel carriers are in the offing. These, although not yet in the hands of troops, are soon to be operational and will back

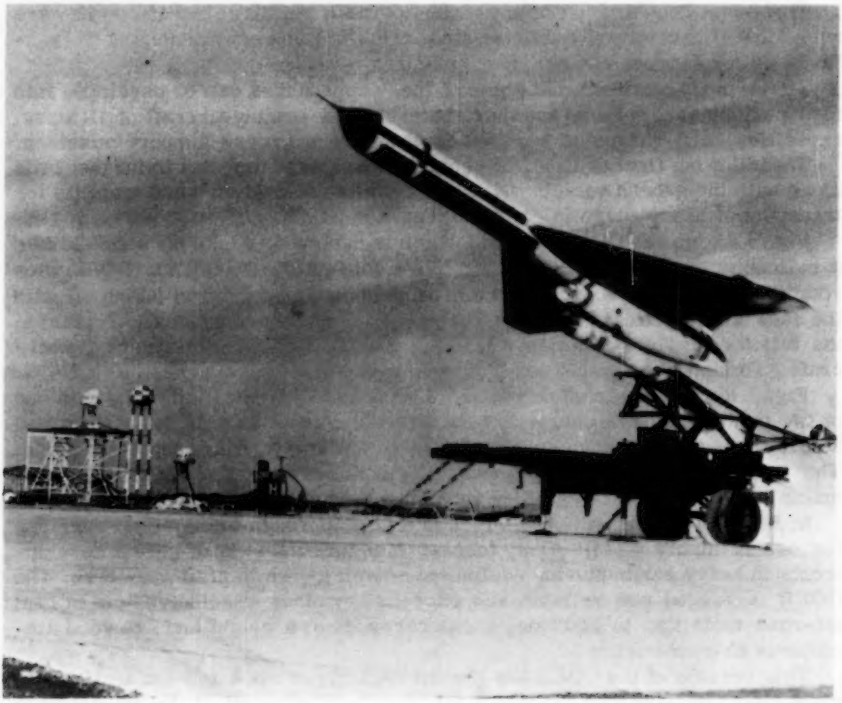

FIG. 5.—USD-5

up the striking power of the Army's powerful new weapons systems. These ground vehicles represent great improvement over today's tanks and armored personnel carriers, in size and weight and in engine performance and fuel economy. Where possible, they will have both swim and air-transportable capabilities.

For better ground or battlefield mobility, as mentioned earlier, Army Research and Development is concentrating on the air.

The air offers the medium for revolutionary improvement in speed of movement. As a consequence, work is proceeding to develop the right air vehicle to utilize it. Plans call for a vehicle that will fly just above the "nap of the earth," permitting the combat soldier of tomorrow to overcome normal terrain obstacles, such as mud, swamps, rivers and forests. This type of aircraft will have the take-off and landing characteristics of the helicopter coupled with the advantages of the fixed-wing aircraft in forward flight.

Some of the experimental prototypes or flying test beds look like disks or platforms, propelled by unusual power plants, but it is hoped that one or two will eventually provide the answer of flying low, fast, slow and quietly just above the battlefield.

These test beds are not in any sense operable military aircraft; some have wings that tilt, others have ducted fans, and a few use applications of conventional power sources and schemes of flight.

The Army is confident that some of these approaches can be developed into high-performance vertical and short-take-off-and-landing aircraft of all sizes, capacities, and ranges to be used for numerous ground support missions.

The following figures illustrate some of these experimental flying test beds along with the ground vehicle that gives promise of true off-road mobility for transport of heavy cargo in combat areas, the GOER.

Fig. 6 shows the DOAK test bed which is designed to take off and land like a helicopter but operates in the air like a conventional airplane. DOAK uses rotatable ducted fans as its source of propulsion. It is pictured taking off with the fans at a vertical position. The propeller ducts are gradually rotated to the full forward position permitting normal flight characteristics of the aircraft. To land, the engines are returned to the vertical.

Fig. 7 depicts the test bed called the PIASECKI flying platform. It is one of two models that are currently under development. This model uses ducted fans for its source of propulsion and has conventional type helicopter controls. The operation in this stage of research is cumbersome, and much work remains to be done before stability and control reach the level desired.

In Fig. 8 is the cargo GOER which is a new approach to logistical carriers for use in highly mobile Army forces. It is an outgrowth of recent developments in heavy earth-moving equipment so well known to civil engineers. The GOER is rugged and reliable and exceeds any other wheeled vehicle in real off-road mobility. In addition, it can carry its own weight and has good amphibious characteristics.

This version of the GOER has the lift capacity of six 2 1/2-ton trucks. Its exoskeletal construction, in which the structural strength of the vehicle is in its outer frame, also permits the vehicle to swim on water. Waterproof parts or submersible engines are unnecessary. The treads of the large tires act like paddle wheels to propel the vehicle at a speed of about 3.5 knots in calm water.

Prototype GOER's initially will be produced in three versions: a 5,000-gal tanker, a 16-ton cargo, and an 8-ton cargo.

A major contribution towards improving cross-country mobility will come from the Army's ground mobility research program. Here, a variety of studies seek to isolate the primary factors influencing soil trafficability and to examine the over-all influence of terrain on military operations.

More important, by far, is research aimed at discovering the behavior of soils under the traffic of vehicles. How the weight, driving, turning and stop-

FIG. 6.—DOAK

FIG. 7.—PIASECKI

ping forces of a vehicle are transmitted to the supporting soil by various configurations of running gear such as tracks, conventional wheels, and very large and soft tires are being examined. It is now known that these forces sometimes are transmitted to the soil in magnitudes that differ markedly from previously accepted theory. The discovery of what actually happens and why may make it possible to improve vehicle trafficability by redesign of running gear.

Efforts are also aimed toward the compounding of a new chemical for specific use as a soil stabilizer. At the same time, techniques such as electro-osmosis and quick-freezing to exploit any and all possibilities must not be overlooked.

Developments in the field of military bridging are interesting and have been reoriented towards the future battlefield. The most startling, by far, is the

FIG. 8.—GOER

development, now underway (1961), of a highly mobile floating assault bridge-ferry for use in getting combat troops across inland water barriers.

Fig. 9 shows an artists concept of this development intended to produce a highly mobile, Class 60, rapidly erectable, floating assault bridge.

This equipment consists of two major components, an amphibious bridge unit and an amphibious ramp unit.

The bridge and ramp units are similarly constructed. Each unit transports about 25 ft of roadway which is carried longitudinally in road travel, with curb section folded. On entering the water, the deck section is rotated 90° by hydraulic power and automatically unfolds to full roadway width of about 13 ft.

Erection of a bridge will be possible at a speed of 400 ft per hr, and the bridge when assembled can handle a high volume of combat traffic—about 400 vehicles per hr.

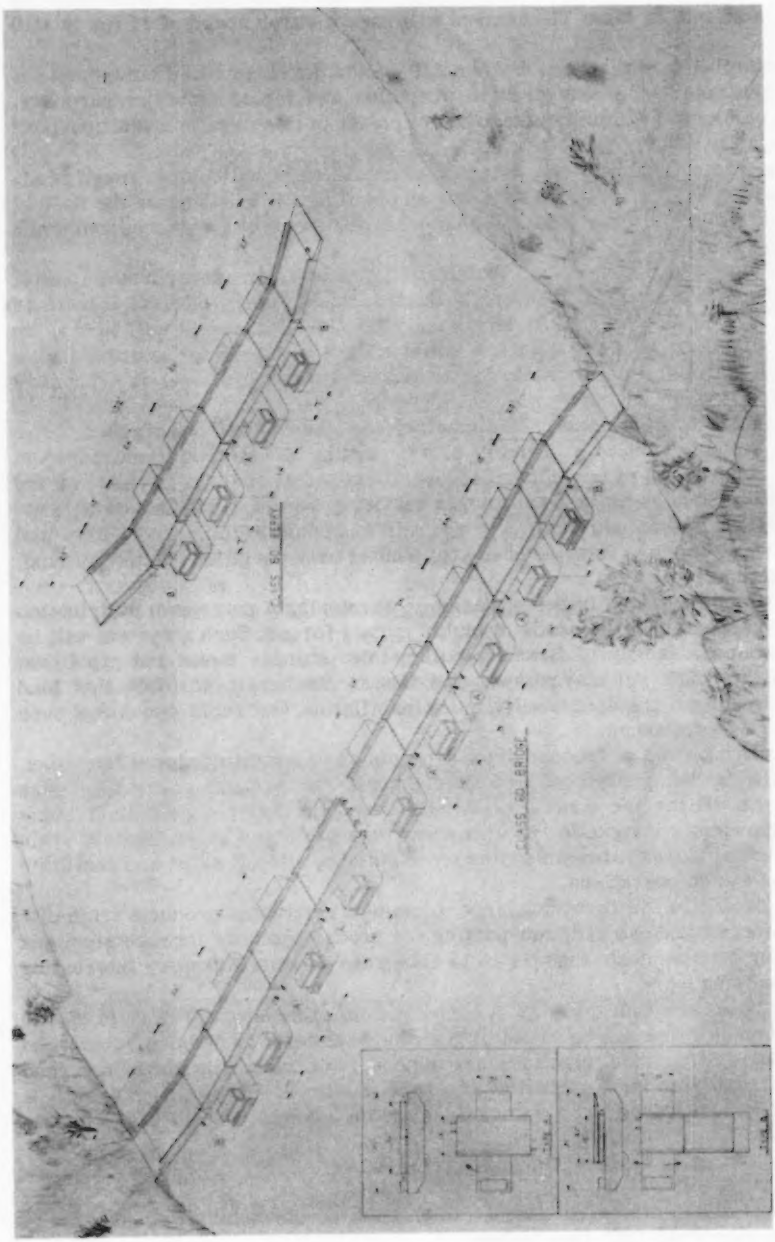

FIG. 9.—ASSAULT BRIDGE-FERRY

On the other hand, mobile assault ferries can be assembled after entering water in 25 min or less. The ferries will have a water speed of 11 fps in still water.

Substantial progress has been made in the development of equipment for rapid clearance of enemy-created obstacles and for construction purposes. One of our most promising pieces of equipment in this area is a multipurpose tractor shown in Fig. 10.

This tractor will have the essential capabilities of bulldozing, rough grading, and excavating by earth scraping and hauling. It will obviate the need of many of the bulldozers, graders, scrapers, and some of the cranes and dump trucks now in military use.

Its overall dimensions and weight will make it air-transportable, and it will float with normal loads. When ballasted, this tractor will have a drawbar pull of 24,000 lb to 32,000 lb; on normal, dry, level terrain it will have a top speed of at least 30 mph. It will be powered by a compression ignition engine and have sufficient fuel capacity for at least 200 miles of travel on secondary roads.

There are two versions of this tractor, one wheeled and one tracked.

One salient point must remain clear. In all our efforts to increase the speed of movement of our combat troops, the fact that success in battle stems from continuous logistical support is not being overlooked. Logistical support must be maintained right up to the individual soldier in the front lines and to get it there we are interested in all forms of transportation—water, ground, air, and pipeline.

Increased emphasis is being placed on developing a petroleum distribution system responsive to the needs of highly mobile forces. Such a system will be built around a family of flexible, collapsible, storage tanks and pipelines; lightweight, high volume pumps, and tanker discharge facilities that lend themselves to air transportability, quick installation, and rapid movement over considerable distances.

To gain a degree of freedom from dependence on established port facilities, emphasis is being placed on the development of logistical over-the-beach equipment. Tests are continuing on the Barc, the Army's giant amphibious cargo carrier; construction is under way on a prototype beach lighter. This beach lighter will expedite unloading from roll-on, roll-off ships and facilitate over-the-beach operations.

POL facilities for receiving large volumes of petroleum products from off-shore moored tankers and transporting the products ashore through pipelines are under development. Figs. 11 to 13 illustrate some of this very interesting and promising work.

Fig. 11 shows this concept utilizing a bulk steel storage tank of 50,000 barrel capacity that can be towed to position when fully loaded and submerged off-shore. Submarine pipelines are placed from tanker to the submerged terminal and from the terminal to on-shore pipelines.

Another facility will be a submarine pipeline system. Fig. 12 is the installation of such a system.

This system provides for off-loading tankers from off-shore open sea moorings.

Fig. 13 illustrates still another utilization of the submerged hoseline to unload a converted LST-type tanker.

FIG. 10.—WHEELED TRACTOR

FIG. 11.—SUBMERGED TERMINAL SYSTEM

FIG. 12.—SUBMARINE PIPELINE INSTALLATION

FIG. 13.—BULK TRANSPORT UNLOADING

This paper has given but a small insight into the Army Research and Development Program. This, and all our work, is being done to insure the continued defense of our nation. Army Research and Development views all these contributions to the defensive might of America with pride; equally important is the fact that many of them will redound to the peaceful benefit of mankind.

Never forget for a moment the underlying cause for our tremendous military effort. Our Army must not relax its guard nor its efforts to build continually better defense forces.

Today, in this surging era of great change, in this age of seeming grayness and indecision, the development of adequate means to advance the progress and security of this country and the rest of the Free World is well within our capabilities if strength is known.

It is important to remember that in the fields of science and technology our nation still has significant advantages over the Communists. To be more aware of these superior edges and strive not only to maintain but to extend them is today's challenge.

No profession can look back with more pride or look ahead with more optimism than that of civil engineering. From the impetus given to this field 150 yr ago by many graduates of West Point until now (1961), the technological advancement of our country and much of the world evolved from the brain cells and toil of civil engineers.

In Latin America and Africa alone, it would take 50 times our present engineering capacity to bring them abreast of our status by the turn of the century. Think of the roads and bridges, the river and power developments, the building and other construction of all kinds needed. The more extensive use of unskilled, indigenous labor emphasizing full employment contrasted to full use of powered equipment will be challenging. An amazing era ahead will challenge our policies, our resources and our technology in the stimulating field in which you labor. The challenge can be met if collective wisdom of all directs it.

This is where a continuous catalytic action is required. It is a national task, and it depends on industry, labor, government, and the Armed Forces. It is also an individual task, depending on every loyal American.

In this age of change, realize that time is of the essence and that faith, not fear, and courage, not complacency, are the keys to our survival. Despite the seething whirlpool of Communism and chaos, our nation must bear the standard. Victory is for those who dare.

Shakespeare said:

"There is a tide in the affairs of men,
Which, taken at the flood, leads on to fortune;
Omitted, all the voyage of their life
Is bound in shallows and in miseries.
On such a full sea are we now afloat;
And we must take the current when it serves,
Or lose our ventures.

CONCLUSIONS

1. In the present era of revolutionary progress in science and technology, the United States Army is faced with an acceleration of obsolescence in all its weapons and equipment.

2. The basis of military power is shifting more and more to research and development and how well a nation makes use of its technological talent in improving the ability of its military forces to move, shoot, communicate and to do this better than any potential enemy.

3. Basic research, being but the applied research of tomorrow, is the key to technological progress.

4. Support of basic research must be increased not only by government but by industry and educational and non-profit institutions.

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RESEARCH AND THE PROFESSIONAL SOCIETY[a]

By Arthur T. Ippen,[1] F. ASCE

SYNOPSIS

Basic and applied research in science and engineering of greater scope and with increased expenditures of public and private funds are today accepted as national obligations. The special challenge to civil engineers to participate in the advancement of new knowledge for a better human environment is outlined with respect to tasks and responsibilities. Present research activities of the ASCE are reviewed and new areas for expanded research efforts are presented. The importance of a revitalized and creative climate for the advancement of knowledge in the profession is stressed as a prerequisite to professional stature and growth. A course of action is suggested to assume new basic research functions by the ASCE as a matter of policy and in line with the constitution of the Society.

THE PUBLIC CHALLENGE

The advancement of basic and applied research in the sciences and in engineering is a matter of pressing national importance today (1961) and has been recognized as such on a non-partisan basis by the political leaders of our country. We are increasingly committed to the advancement of science and technology through education and research by large scale provision of public

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[a] Presented at the October 12, 1960 ASCE Annual Meeting at Boston, Mass.

[1] Member and Past Chairman of Research Committee, Prof. of Hydraulics, Hydrodynamics Lab., Dept. of Civ. Engrg., MIT, Cambridge, Mass.

and private funds for this purpose. This conclusion has been reached inescapably as the result of our vital responsibilities for the ultimate survival of free society throughout the world. It is accepted as the governing social thought today with regard to our national and international interests and relations.

This expansion of scientific and engineering efforts must not be channeled solely into the direction of military defense and security but also, more importantly, into those fields that ultimately give promise for stable and free social systems in the world. Their survival and development requires solution of pressing economic and technical problems of higher living standards for the rapidly expanding populations. These problems are predominantly concerned with the reshaping of human environment on a staggering scale, and new and imaginative avenues for free and more rapid human progress are necessarily called for. This challenge has come to press on us as the result of the increasing power of regimented societies in the Marxist world. It is the result not so much of their military achievements, but of the all too slowly evolving but unavoidable insight on our part that their challenge is a total one. It demands and must get a total response. It will require, in addition to the shooting off of space vehicles into a near vacuum beyond the earth, the infinitely more complex firing of human hopes right through the continents around the world with an intensity not to be slowed by the mass of human problems to be conquered. We must reach the stars in the eyes and minds of all humanity and convey the message that a life in freedom and dignity is not only fully compatible with all material aspirations but is indeed the better and faster way to achieve them.

RESEARCH AREAS FOR CIVIL ENGINEERING

It is in this less publicized sphere of action that our profession should recognize its natural challenge and in which our Society of Civil Engineers in particular should undertake to lead and to find new tasks.

What are some of these tasks? On the national level we are faced with the ever increasing problems of the urbanized and industrial society in relation to a not only liveable but better physical environment. Cities have haphazardly grown into obsolete piles of masonry repelling and degrading life instead of attracting it. Their redevelopment into centers of economic and cultural productivity poses not only technical problems but requires the synthesis of economic, social, and cultural factors with technical functions.

New frontiers of functional and aesthetic planning together with the use of new materials and of new construction methods are in need of definition and development. Intimately associated with the planning and creation of a better human environment are the public health aspects; the pollution problems encountered with water and atmosphere; and the provision of effective urban, suburban, and interstate transportation systems.

For these tasks extensive research is needed on almost the entire front: from the basic scientific problems of a highly specialized nature, through the translation of the fundamanetal knowledge into technical capability, to the synthesis of design, construction, and management with the desired social and cultural environment of the community.

Economic analysis must not be directed solely to the abstract utility of structures erected for whatever purpose, but should also include their broad

and perhaps intangible effects on the surrounding life. A good example of this is the Prudential Center now (1961) under construction in Boston, where local tax concessions were thought well worth the price in view of the expected boost to the morals and general revival of the community.

On a wider plane, under the impact of population growth, all civilizations are confronted presently with a complete rethinking of the problems of water availability and use. There is no other natural resource of comparable breadth of importance for human and industrial use, for power and transportation, for food production, and for recreation. Where, formerly, the direct use of water by man was small in terms of total natural supply, today the waters of our streams are often serving several times over a variety of human functions before reaching the oceans. This rate of utilization may increase by an order of magnitude within a generation, and new sources and new methods of reuse are to be found, offering a vast field for scientific and engineering exploration of basic principles and of new technologies.

In the search for new fundamental knowledge, in the planning and design phases, and in the execution of civil engineering works new tools and new materials have come rapidly into being in modern times. Methods of analysis and of recording of data are available for all phases of our professional activities that have revolutionized planning and design procedures and that make practical the application of new and refined theoretical concepts and methods of analysis and synthesis. A more basic understanding of the properties of new and of conventional materials permits more confident application in our structures with less dependence on time-honored and often obsolete "factors of safety." The many tasks and new tools are on hand for the revitalized growth of the profession, and research on a broad spectrum is the road on which this profession also must advance.

THE PRESENT BALANCE

It has been emphasized frequently that the civil engineer is the servant of the public, and the writer certainly does not propose to detract from this role of the honorable and dependable trustee and executor of public works, to whom the design and construction phases may be delegated with confidence.

We stand in need, however, of being aroused again to the principle that, ultimately, professional quality and status are measured by the degree of leadership exerted through the members of the profession; leadership in the advancement of new knowledge, in the creative use of modern science and technology, and in the stimulation of the public towards visions of a better human environment. The challenge in Civil Engineering is as demanding and exciting today as in any other field. The writer has tried to indicate some of these to support this contention. The next task before us is to analyze what we, as a professional society, are doing presently to advance progress in our field and, more importantly, what we might be doing and are obligated to try to do in the future.

The writer has finished a 4-yr assignment on the Research Committee of the Society that has been a fruitful and rewarding professional experience. During these years this committee has seriously concerned itself with the basic constitutional objective of the Society: the advancement of the science and profession of civil engineering. It has concluded that too much emphasis

has been placed in the recent past on matters pertaining to the advancement of the status of the profession ignoring largely the first aim of the science of civil engineering. The committee has further concluded that this first aim is ignored only at the peril of the second, and that the lack of status of the profession in the public mind is logically tied to the neglect of the advancement of new knowledge by civil engineers as a group. A climate of apathy and indifference toward research exists, and civil engineering does not share in the rapid scientific and technological progress in the world to the extent commensurate with its inherent task in society.

WHAT WE ARE DOING NOW IN THE ASCE

Within the last few years a number of measures were taken to establish a new research consciousness as a dynamic component of professional growth. These may be summarized as follows:

1. All 14 technical divisions have now established research committees, many of which are actively engaged in identifying research needs and formulating specific research proposals.
2. The Research Committee with the active support of the National Science Foundation and various educational institutions organized annual Research Conferences with the aim of defining basic needs and of making specific proposals to the Board of Direction for the support of research activities. Two reports have been published on "Basic Research in Civil Engineering"[2] and on "Research Objectives and Organization."[3] The 1960 Research Conference formed the third research conference in this series.
3. Five Research Prizes are now awarded every year with the cooperation of the research committee of the Technical Division, particularly aimed at the encouragement of younger members and in recognition of persistent research efforts and excellent achievements.
4. The Society has established from current income an annual Research Fellowship of $5,000 for the pursuit of basic research in civil engineering by the best qualified graduate student at a recognized institution.
5. A Research Luncheon at the mid-winter meeting of the Society is held annually to which a speaker of national prominence is invited for the purpose of stimulating research interest in the membership. Three of these addresses have been published.[4,5,6] The research prizes are awarded on this occasion, and the winner of the annual research fellowship of the Society is announced.
6. The most effective way for the advancement of research aims in a specific area of interest has been the organization of Research Councils with

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2 "A Conference on Basic Research in Civil Engineering," Record of Addresses and Reports, sponsored by the ASCE, Natl. Science Foundation and the George Washington Univ., September 10–11, 1958.

3 "A Conference on Research Objectives and Organization – The Second Conference on Research in Civil Engineering," Record of Addresses and Reports, Sponsored by the ASCE and the Technol. Inst. of Northwestern Univ., September 10–11, 1959.

4 "The Responsibility of a Profession for Developing New Knowledge," by M. A. Mason, Civil Engineering, June, 1958.

5 "Great Opportunities in Civil Engineering Research," by Lee A. DuBridge, Civil Engineering, April, 1959.

6 "The Role of Research in Civil Engineering," by Morrough P. O'Brien, Civil Engineering, June, 1960.

a membership of scientists and engineers specializing in the area concerned with certain financial and administrative responsibilities without infringement on their essential autonomy in setting research goals and in the solicitation of funds. A number of Research Councils have functioned in the past under the "Engineering Foundation" receiving token support. Several of these are now (1961) under ASCE sponsorship, due to the impending reorientation of the aims of the Engineering Foundation. New councils, however, have been formed and it is believed that this type of research team provides an efficient mode of research promotion in a given field.

7. All research activities of the Society will receive, in the future, considerable coordination and direct support through the establishment at Society Headquarters of the office of Director of Research. The funds to make this possible have been appropriated in equal shares by the Engineering Foundation and by the Board of Direction of ASCE. Needless to say, the Research Committee does not visualize this office merely as an expansion of administrative functions, but expects that it can be staffed by a recognized leader in research who can effectively stimulate our own activities on a broad basis as well as promote the much-needed interest of private and public agencies in the instigation and support of research projects in civil engineering.

FUNDS COMMITTED

Following this organizational summary of Research Committee's activities in support of civil engineering research, it may be well to add the present financial commitment of the Society in this direction. This is difficult because there is no specific budget for the activities of the Society that might be classified under research. Let it be acknowledged here again that all Technical Divisions have research committees, provided for in their own budgets, and that many technical committees of the Divisions are concerned with research activities; indeed, the Engineering Mechanics Division may be counted entirely in this category. The Society also performs an extensive service to research interests through its system of publications, which is in the process of continuous improvement and accounts for a major share of the Society's expenditures. There is presently no way of evaluating the total of financial contributions for these servies, and only the budget of the Research Committee gives a direct, if incomplete, indication of funds allocated to research activities by the Society. For the fiscal year October 1, 1960 to September 30, 1961 this budget was as follows:

Administrative Expenses	$ 2,500
Research Prizes	500
Research Fellowship	5,000
Office of Research Director	20,000
Research Conferences	4,500
Total	$32,500
Contributed by Eng. Foundation	10,000
Net cost to ASCE	$22,500

Although this budget has shown a gratifying, almost tenfold, increase in recent years, it is by no means adequate to sustain the program of research activities, which, in the opinion of many members, is vital to our profession. It is certain

that for the dynamic program so essential to professional growth much larger funds must be expended in the future, either from internal sources or solicited from outside. Several other professional societies have supported basic research for many years as a matter of policy. It may be helpful at this point to mention that the American Society of Mechanical Engineers (ASME) has aided research activities for many years through sponsorship of specific projects to the extent of $750,000 per yr; naturally, the major portion of this amount came from industrial sources. On the other hand, the total funds available for civil engineering research conducted by all the Research Councils under the sponsorship of the Research Foundation may be estimated at less than $250,000 per yr. A number of government agencies sponsoring basic research primarily in academic institutions have allocated for example in 1957 only $300,000 out of a total $24,300,000 to civil engineering research, whereas more than ten times this sum was provided for each of the other engineering fields.

More importantly, the National Science Foundation according to recent estimates has been able to support only about 1/4 of the research proposals judged as meriting financial assistance; and from this information it can be concluded that requests in the civil engineering area alone amounting to $1,500,000 could not be granted. This present inadequate state of basic research support for our field is amply documented in the previous reports of the Research Conferences.[2,3]

WHAT NEEDS TO BE DONE?

The future requirement for the survival of the profession and the ASCE as its public spokesman is a rigorous and responsible reaffirmation and pursuit of its basic constitutional aims. An overall review is indicated of all Society activities in the light of modern scientific and technical developments and of its reflection on the future of civil engineering practice. Rightly or wrongly the general public no longer associates our work with the forefront of engineering advances, but looks on it more and more as an auxiliary function for design and planning in other fields, to which the initiative has often shifted. In turn, this public attitude is felt in our lack to attract our share of promising young people into our profession or even to retain many others whose interests are excited towards the exploration of new technical frontiers. In re-evaluation of its basic role, the education of the civil engineering student is already moving rapidly to a broader foundation in the fundamental and engineering sciences in the undergraduate years and towards graduate studies as the more professional terminal phase of formal training. Such training should comprise throughout creative investigations as essential components of the educational experience for student and faculty alike. The profession cannot escape to associate itself most intimately with this learning process and indeed must welcome and promote it. It must become more deeply involved in supporting it. Thus, new ideas and methods are projected more readily into future practice and, in turn, the practitioner willing to pioneer finds a positive response to any concrete challenge for new answers.

Research reveals how things are and thus probes in depth. But it also permits us to perceive how things might be and what better works there might come into being. With this must be coupled, as understanding and vision grow, increasing comprehension of the place of things in relation to a complex

material and mental environment. Human progress depends on the successful synthesis of complicated technical systems with economic, political, and general human factors.

Creative engineering thus demands a modern engineering mind capable of detailed analysis and yet of encyclopedic breadth; it demands closeness to basic principles and distance to discern unity in the interplay of all forces; it demands less concern with established techniques and codes and more flexibility to compose new links into new frames of conception.

This is the problem that our time has set for engineering and particularly for our profession. In line with this challenge stepped-up efforts must be aimed at expansion of knowledge in the three phases of research: discovery and development of basic principles, adaptation to practice, and organic synthesis of engineering systems with all environmental conditions. This task should be accepted anew as essential to professional stature and growth. It requires reorientation of the engineering mind from the resigned acceptance of yesterday's codified knowledge for today's routine solution to thoughts of tomorrow's possibilities in terms of today's research. Our Society functions must be bent towards the generation of this mental climate, so that members and public alike sense in our activities a greater promise and challenge for the future. To those ends the following suggestions may serve as tentative guiding principles.

SOME GUIDING PRINCIPLES

1. The present frame of our research organization must be strengthened and greatly expanded. The leadership of our Technical Divisions and of their research committees should have an effective and direct voice in establishing Society policy through representation on the Board of Direction.

2. The research areas of broad and major significance to the profession should be identified and appraised in collaboration with scientists and engineers in all professional fields involved. Interchange of ideas and visions between all learned disciplines should be initiated and systematically fostered through discussions on a wider scale with the above aim. Society membership should be open to all actively engaged in civil engineering research and development regardless of original background.

3. The research directed activities of the Society should be given prominence in all professional publications, and papers dealing with future developments and possibilities should be invited in addition to comprehensive evaluations of the state of the art.

4. Specific research tasks are to be outlined through the Technical Divisions and all members, but especially younger members, should be encouraged to undertake them under Society sponsorship.

5. Needs and opportunities in civil engineering research must be more effectively presented to industry, consulting firms, and governmental agencies with the aim of strengthening their own internal program and of securing vastly increased support for our activities and project. Too frequently the present inadequate funds allocated to research in some of these agencies are subverted to other uses through lack of recognition of their importance and through short-sighted and narrow interpretation of the function of research.

6. To enhance its moral position for eventual outside support, the Society should assume increasing financial responsibilities for research and direct sponsorship of projects of unusual scope and promise. In this connection, the research committees of several Technical Divisions have proposed repeatedly the establishment of a special research fund to be financed by a definite increase of dues.

7. Beyond the more immediate confines of its own research interests, the Society should strive to represent the profession effectively in all councils of national and international bodies through which policy pertaining to science and engineering is shaped. This requires, again, first the strengthening of our own research position.

8. The possibilities of a better human environment through research as well as significant advances and accomplishments should be effectively publicized through press, radio, TV, and film media with modern methods and mass appeal.

9. The thoughts, philosophies, and personalities of leading scientists and engineers should be brought before our members not only at large conventions but also at local section meetings, through national lectureships of the society, and through free forums for the discussion of present and future tasks.

CONCLUSIONS

This review of possibilities to recondition the research climate and to regenerate the basic functions of the Society is not meant to present a complete course of action. It represents only what the speaker was able to compose for this occasion within his allotment of time, from the thoughts of others, and from his experience with the present research activities of the Society. It is certain that many members could greatly add to this summary by suggesting additional approaches and suitable measures to be followed. They are cordially invited to establish contact with the various Research Committees of the Division to this end.

In an essay of Ralph Walter Emerson's the following passage is found: "the quality of the imagination is to flow, and not to freeze. The poet did not stop at the colour or the form, but read their meaning; neither may he rest in this meaning, but he makes the same objects exponents of his new thought." This is, in essence, the message that we should find in all our tasks as professional people. Progress has been made, but the rate of advance has been too slow and restrained. The preceding suggestions, and probably many others, must be implemented with a sense of urgency. If our concern and willingness for determined action can be communicated to the general membership, a major step will have been accomplished in moving towards the creative forming of human environment as the modern challenge of civil engineering.

Journal of
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ATOMIC POWER, A FAILURE IN ENGINEERING RESPONSIBILITY[a]

By Adolph J. Ackerman,[1] F. ASCE

SYNOPSIS

This paper discusses the application of the new scientific development of atomic power for public service, which has appeared on the national scene following the end of World War II. In this short span of 15 yr, the spectacular new energy resource of the atom has attained a stature which to some people is exciting, to others fearsome, and to most everyone highly mystifying.

A brief historical review is presented, with an outline of basic legislation, governmental controls of policy, a demonstration program of power reactors, and the hazardous features of the new science. Of primary interest to all engineers, and particularly to independent consulting engineers, is the question of public safety and the overriding responsibility of professional engineers to protect the public against the unprecedented hazards which are involved in the operation of an atomic power plant.

Reference is made to the private insurance industry's inability to write adequate third-party liability insurance. As a consequence, most of the burden of paying indemnities, following a major disaster, has been shifted to the taxpayers. This, in turn, has created incentives for the selection of sites for atomic power plants which tend to increase the hazard to the public and which violate the basic responsibilities of the engineering profession. An example is presented where a new atomic power plant has been constructed near a large population center. Court action was initiated to halt construction of this plant. When these proceedings reached the United States Supreme Court, the writer

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[a] Paper to be presented at the Annual Meeting of the ASCE Tennessee Valley Sec., at Knoxville, Tenn., in November, 1961.

[1] Cons. Engr., Madison, Wis.

was nearing the end of a ten-year research effort for a book on "Facts and Fallacies in Atomic Power." Because it appeared that the court would be confronted with some highly complex technical questions and unprecedented responsibilities which should be of primary concern to professional engineers, the writer was granted the privilege, by the Court, of presenting part of his findings in the form of an "amicus curiae" brief. The brief is included as an appendix to this paper. It provides an example of the privileges and obligations which a professional engineer may exercise under our judicial system in an effort to protect the public interest.

POSTWAR TRANSITION IN BASIC RESPONSIBILITIES

The vast complex of facilities required for the production of the first atomic bombs was constructed at Hanford, Washington, and Oak Ridge, Tenn., in the remarkably short period of three years, from 1942 to 1945. This tremendous performance in simultaneous research, design, and construction had demonstrated what can be achieved (in time of war) by taking a new technology and developing it under a combination of unrestricted governmental authority and unlimited supply of governmental funds. Such a policy of direct governmental action, as a temporary but essential wartime measure, is generally accepted by the American people to assure the preservation of their republican form of government. But, by the same token, a primary objective (with the end of war) is the return, as rapidly as possible, to the constitutional processes of government and the normal forms of commercial enterprise.

In retrospect, for most industrial enterprises, the postwar transition to a normal commercial activity took place under the traditional system of free enterprise, economics, localized responsibility, and the Rule of Law. However, no such combination of traditional guidelines existed for the commercial applications of the hazardous new science of atomic fission. Furthermore, at this stage, all of the government-owned facilities for the production of fissionable materials were considered, primarily, as of continuing great military importance, and were confined behind a vast wall of secrecy. These facts contributed to the decision to maintain basic control of the new science in the form of a continuing governmental monopoly.

Ever since the first sustaining chain reaction was accomplished in 1942, there was no doubt about the technical feasibility of producing electricity from heat generated by the fission process. In time, various proposals were advanced to utilize the heat from a controlled atomic reaction for the production of steam to drive a conventional steam-electric generating unit. (In terms of a conventional fuel-burning steam plant, the steam boiler unit would, in effect, be replaced by an atomic reactor.) The practical problems, however, were quite obvious even at that time; in fact, it seems that as more knowledge was acquired, the practical problems loomed constantly larger. In particular, there was no early prospect of bringing down the cost of atomic power to a level of costs which prevail for conventional thermal or hydro power.

LEGISLATION OF 1946 - ATOMIC ENERGY COMMISSION

The "Atomic Energy Act of 1946" created the Atomic Energy Commission and established a first stage of legislation for the development of electric power

from atomic fission. It was recognized at that time, as stated in the "Declaration of Policy" of the Act, that "the effect of the use of atomic energy for civilian purposes upon the social economic and political structures of today cannot now be determined. It is a field in which unknown factors are involved. Therefore, any legislation will necessarily be subject to revision from time to time. It is reasonable to anticipate, however, that tapping this new source of energy will cause profound changes in our present way of life."

Unfortunately, the effect of the "Atomic Energy Act of 1946" was to make it practically impossible for the private power industry to participate in the development of atomic power for commercial purposes.

During the late 1940's the Atomic Energy Commission (AEC) undertook the development and construction of four atomic reactors that were intended to provide experience in the construction and operation of such devices. In 1950 the AEC received expressions of interest from various industrial groups who wanted to explore the possibilities of developing the commercial aspects of atomic power; this interest was further stimulated during the period of 1950 to 1953.

ATOMIC ENERGY ACT OF 1954

In February, 1954 Congress began consideration of major revisions in the Atomic Energy Act which finally culminated in the "Atomic Energy Act of 1954." The new Act introduced the following principal changes:

(a) It relaxed statutory restrictions against ownership or lease of fissionable material and of facilities capable of producing fissionable material.

(b) It permitted private manufacture, ownership, and operation of atomic reactors and related activities, subject to necessary safeguards under licensing systems administered by the AEC.

(c) It authorized the AEC to establish minimum safety and security regulations to govern the use and possession of fissionable materials.

(d) It permitted the AEC to supply special fissionable materials and services to licensees for the operation of reactors, at prices to be established by the AEC.

(e) It liberalized the patent provisions of the Atomic Energy Act to a limited degree.

Since the time the "Atomic Energy Act of 1954" became law, there have been a number of amendments, some of them relatively minor and others of considerable importance.

The legislative history of the "Atomic Energy Act of 1954" shows quite clearly that Congress favored an active industrial program of participation in the development of atomic power. For example, when the Joint Committee on Atomic Energy reported the proposed legislation for consideration by Congress the majority stated: "We do not believe that any developmental program carried out solely under government auspices, no matter how efficient it may be, can substitute for the cost-cutting and other incentives of free and competitive industry."[2]

However, responsibility for the development of atomic power was not turned over to industry by the Act of 1954. The Act authorized and directed the AEC

[2] House Report No. 2181, Senate Report No. 1699, 83rd Congress, 2nd Session, 1954.

to arrange for the performance of research and development relating to the use of atomic energy, for the "generation of atomic energy, and a demonstration of the practical value of reactors for industrial and commercial purposes, either through its own facilities or by private or public institutions or persons."

Under the Act of 1954, the government retains ownership, through the AEC, of all rights, title and interest in the special materials, such as uranium or plutonium, which are capable of releasing substantial quantities of atomic energy. A private company owning an atomic power plant is prohibited from owning the special atomic materials, or "fuel rods," which are the basic source of the heat energy. Such materials must be borrowed or leased from the AEC, subject to what the Atomic Energy Act defines as a "reasonable charge."

DEMONSTRATION PROGRAM OF POWER REACTORS

In January, 1955 the AEC announced its demonstration reactor program, in which it offered to underwrite a part of the cost of certain atomic power projects. In January, 1957 the AEC expanded this program by inviting proposals to design, construct, and operate atomic power plants. No limitations were placed on the types or sizes of plants which could be proposed, other than that they should make significant contributions toward the achievement of commercial atomic power and that construction should be completed by June, 1962.

During the past six years the AEC has issued licenses to nine private utility groups for the construction of atomic power plants ranging in capacity from a small one of 17,000 kw to the largest one of 150,000 kw. Available cost estimates for six of these projects indicate a total of $280,900,000. Of this total the AEC has committed itself to the payment of subsidy contributions in the total amount of $57,200,000.

The AEC has also licensed four public power groups for the construction of somewhat smaller plants ranging in size from 10,000 kw to 75,000 kw. The available cost estimates indicate a total of $131,400,000 for these four plants, and the AEC has committed itself to subsidy contributions amounting to a total of $96,800,000.

RADIATION AND ITS EFFECT ON HUMAN BEINGS

Prior to the development and use of the atomic bomb in World War II, radiation injury was a relatively rare occurrence and, when it did occur, it was usually confined to scientists or other specialists working directly with such early developments as x-rays. As a consequence the general public has almost no knowledge, and very little concern, about the possible harmful effects of radiation. Even the vast amounts of medical information and other statistical records which were accumulated in Hiroshima and Nagasaki have been studied by relatively few people. However, there is no question about the importance of radiation as a significant factor which must be taken into consideration when atomic power and its uses are discussed.

Unfortunately it is not feasible to enlarge on this extremely important subject in the present paper. However, it may be stated briefly that the harmful consequences of radiation fall into "short term effects" and "long term effects." The short term effects (other than immediate death) involve radiation sickness and burns, including injury to the blood cells from which recovery can generally

be achieved by competent treatment within 6 months to 1 yr. The long term effects of radiation on human beings consist of general reduction of the life span, the induction of cancer, and the propagation of harmful effects to the next generations of offspring.

NEW AREAS OF PROFESSIONAL RESPONSIBILITY

The introduction of the new science of atomic power has brought with it two new areas of responsibility which should be of particular concern to the engineering profession. The first relates to the safety of operating personnel in atomic power plants and to the safety of the public living in the vicinity of such plants. This area of responsibility is of primary concern in the present paper.

A second and very important area of responsibility relates to the disposal and storage of radioactive wastes from atomic power plants. The following brief quotation will suffice to identify the importance of this new responsibility:

> "In the current wave of enthusiasm for nuclear power, the management of wastes has the position of a step child. One risks being branded a Casandra if he points out, as I am doing, that waste problems may make or break the nuclear power business. A lawyer active in the atomic power field has pointed out that improper disposal of reactor wastes may involve as large a sum for public liability as one of the reactor accidents now receiving so much attention. It may not be fashionable to ponder these problems, but it is nonetheless important to do so while there is still time to avoid serious mistakes."[3]

It has also been pointed out that "the problem of keeping millions of tons of dangerous nuclear waste out of circulation for centuries will become prodigious as more and more atomic furnaces come into use. AEC officials term it 'one of the major challenges of the industry.' "[4]

With respect to the responsibilities of operating a reactor, an acceptable appraisal of the potential hazards can be made only after actual operating experiences, under a variety of circumstances, have produced a significant record of failures. This severe discipline in the advancement of the art of engineering, commonly known as "learning from failures," is well exemplified in the slow and laborious development which has taken place in the design and metallurgy of high pressure steam boiler units.

PROBLEMS OF INSURANCE

One of the noteworthy influences in the development of steam boiler units has been the private insurance industry. This industry has at all times collaborated closely with designers, manufacturers, and operating companies through its own resources of engineering and inspection service. This important resource of professional and business responsibility has made it possible for the insurance industry to provide full insurance protection against the

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[3] Presented by G. Hoyt Whipple, Health Physicist, Univ. of Rochester, Atomic Energy Proj., at the Amer. Industrial Hygiene Assn. meeting, in Philadelphia, Pa., on April 26, 1956.

[4] "The Development of Nuclear Power for Peaceful Purposes," Electrical Engineering, June 1954, p. 498.

consequences of any type of boiler failure, involving not only the physical and personal damage to the power plant and its operators but also to the public living in the vicinity of the plant. The latter protection is provided through "third party liability insurance."

This sense of localized responsibility is a feature of our national economy which deserves special recognition. It represents a unique combination of legal and ethical standards in serving the public interest. In the atomic power field, on the other hand, the insurance companies were confronted with a new and unprecedented peril. After considerable study they were obliged to announce that they would be unable to offer satisfactory public liability insurance on atomic power installations.

A FAILURE IN ENGINEERING RESPONSIBILITY

In March, 1957 the AEC published a report, "Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants," which is generally known as the Brookhaven Report. The results of these studies indicated that, depending on local conditions, the property damage alone could range between $2,300,000,000 and $4,000,000,000, and possibly higher. Damage to health and life could be on the order of 43,000 injuries and 3,400 fatalities, without taking into account the probability of harmful long term effects on several hundred thousand people. The financial liability for human casualties was not evaluated and is, obviously, beyond comprehension.

There are, of course, various alternatives available with respect to site selection to minimize the potential damage in the event of a reactor failure. As a matter of fact, remote locations and long transmission lines have been adopted for many hydroelectric developments. The traditional practice has been to rely on the free interplay of professional engineering and corporate responsibilities to produce an optimum solution of design and site selection for a new power plant. However, instead of relying on such practices for atomic power plants, a proposal was advanced which must be regarded as a great historical tragedy, particularly as it relates to exploitation of public confidence in the engineering profession. In 1957 Congress was persuaded to enact legislation under which the public liability, except for the relatively small coverage offered by the private insurance industry, was transferred to the taxpayers of the nation.

The net result of this action has been to disrupt the traditional system of disciplines and responsibility of the engineering profession. The public has great confidence in the engineering profession to protect the public health and safety, and professional engineers are expected to serve under the highest standards of ethics and intellectual honesty. However, these standards cannot prevail under a system of monetary indemnity which displaces such responsibilities.

THE LAGOONA BEACH PLANT - AN EXAMPLE

Although the issues of public safety apply equally to all atomic power plants, whether publicly or privately owned, a specific case may help to identify the conflicting issues which are currently growing up in the field of atomic power.

Under the Act of 1954, which authorized industrial ownership and operation of an atomic reactor, a group of power companies formed the Power Reactor Development Company (PRDC) and offered to participate in the AEC's "Power Demonstration Reactor Program." This company proposed to develop a "breeder" reactor for the generation of steam, and applied for an AEC construction permit in January, 1956. In June, 1956 the AEC's Advisory Committee on Reactor Safeguards reported on the PRDC proposal and stated in part:

> "The proposed PRDC reactor represents a greater step beyond the existing state of knowledge of the art than any other reactor of comparable power level which has been proposed by an industrial group . . . . The Committee believes there is insufficient information available at this time to give assurance that the PRDC reactor can be operated at this site without public hazard."

Despite this adverse report, the AEC issued a provisional construction permit in August, 1956. Since then, the construction of the plant has been substantially completed and it is now known as the Enrico Fermi Atomic Power Plant. The site, on the shores of Lake Michigan, is about 35 miles from the center of Detroit and about 30 miles from the center of Toledo, Ohio. Important municipal and industrial water intakes lie within 30 miles of the site. Many of the site conditions correspond to the setting which was assumed for the study in the Brookhaven Report. Ultimate capacity is estimated to be 430,000 kw of heat, or 150,000 kw of electricity.

LEGAL ACTION TO STOP CONSTRUCTION

The action of the AEC in granting the PRDC construction permit was strongly criticized in Congressional circles and other groups concerned with safety aspects. In August, 1956, after public release of the adverse report of the Safeguards Committee, representatives of organized labor filed a petition requesting the AEC to order suspension of the construction permit. They alleged that the permit would result in construction of a reactor which had not been found safe, and that operation of such a reactor would create hazards which would imperil lives, health and property. Following hearings held in 1957, the AEC issued its "Opinion and Final Decision" on May 26, 1959. It concluded:

> "We believe the public interest in the development of the fast breeder reactor, the time to be saved in proceeding with construction while the remaining technical and safety problems are being solved, and our responsibilities under the Atomic Energy Act of 1954 are better served by continuing the permit."

Dissatisfied with the AEC's decision, the labor unions petitioned the United States Court of Appeals to review the case. The decision of this Court, issued June, 10, 1960, included the following significant statements:

> "In our opinion the Commission's findings regarding safety of operation are not sufficient.
>
> "The economy cannot afford to invest enormous sums in the construction of an atomic reactor that will not be operated. If enormous sums are invested without assurance that the reactor can be operated with rea-

sonable safety, pressure to permit operation without adequate assurance will be great and may be irresistible.

"We think it clear from the Congressional concern for safety that Congress intended no reactor should, without compelling reasons, be located where it will expose so large a population to the possibility of a nuclear disaster. It does not appear that the Commission found compelling reasons or saw that such reasons were necessary.

"Because we think the safety findings insufficient, we must set aside the Commission's grant of a construction permit. . . ."[5]

In November, 1960, the PRDC and AEC appealed this decision to the United States Supreme Court. On June 12, 1961, the Supreme Court reversed the judgment of the Court of Appeals.[6] It ruled that issuance of the construction permit had complied with the statute and regulations. Unfortunately, the Supreme Court chose to limit its decision to the legality of the construction permit, and to isolate it from the further procedures of applying for an operating permit. The Court stated:

"PRDC has been on notice long since that it proceeds with construction at its own risk, and that all its funds may go for naught. With its eyes open, PRDC has willingly accepted that risk, however great."[6]

Thus, the basic question of operating the atomic power plant remains unresolved. The Court's decision declares:

"It may be that an operating license will never be issued. If one is, that will not be the end of the matter. The respondents may have judicial review."[6]

The minority opinion of the Court declared:

"This legislative history makes clear that the time when the issue of 'safety' must be resolved is before the Commission issues a construction permit. The construction given the Act by the Commission (and today approved) is, with all deference, a lighthearted approach to the most awesome, the most deadly, the most dangerous process that man has ever conceived."

AMICUS CURIAE BRIEF

An extensive research in the field of atomic power had brought the writer to the conclusion that the selection of a site for an atomic power plant is not governed by rules of law, but calls for the application of expert judgment by professional engineers. It is a problem involving great responsibility and technical complexity on which the available knowledge is relatively limited.

It appeared advisable to make the results of this research available to the Supreme Court by exercising the privilege of filing an "Amicus Curiae" Brief. It was hoped that this would contribute to serving the public interest. However, the majority of the Court chose to limit its decision to the legal interpretation of the case.

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5 280 F. 2d 645, 1960.

6 U. S. Supreme Court No. 315 and 454, October Term 1960, June 12, 1961.

The "Amicus Curiae" Brief contains much which is believed to have continuing reference value; it is included here as an appendix. It provides a summary of basic philosophy in a new area of engineering responsibility which demands the attention and critical appraisal of all professional engineers.

The task of attempting to communicate the basic concepts of professional responsibility in non-technical language was not a simple one and, undoubtedly, the present result is not the best. However, it serves to identify the great responsibilities and the duty which confront the professional engineer in this technological age. His failure to meet these responsibilities is bound to add to our national peril.

SUMMARY

Unfortunately, limitations of space have prevented a more detailed exposition of various important matters. To clarify the issues, emphasis has been directed to the factors which relate to engineering responsibilities. It is clear that the basic problem as outlined in this paper remains unresolved. Hence there is much to challenge the resources of the engineering profession, and particularly the independent consulting engineer.

APPENDIX*

In The

Supreme Court of the United States

October Term, 1960

No. 315 and 454

Power Reactor Development Company, *Petitioner,*

v.

International Union of Electrical, Radio and Machine Workers, AFL-CIO, et al., *Respondents.*

United States of America and Atomic Energy Commission, *Petitioners,*

v.

International Union of Electrical, Radio and Machine Workers, AFL-CIO, et al., *Respondents.*

On Writs of Certiorari to the United States Court of Appeals For the District of Columbia Circuit

BRIEF OF ADOLPH J. ACKERMAN, AMICUS CURIAE

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April 1961

* Index and statement of position have been omitted.

REASONS PROMPTING THE SUBMISSION OF AMICUS CURIAE BRIEF

The issues before the Court in this proceeding are of grave importance in the application of the new science of atomic energy for the generation of electricity, and involve heavy responsibilities concerning the health and safety of the general public. Beyond the questions which have been defined in terms of embryonic law and emerging regulatory principles, is the fundamental question whether a potential hazard of unprecedented magnitude shall be introduced in an area where a large population would be exposed to it. The Court's decision in this case is bound to have direct and far-reaching influence on the progress and application of atomic power and on the related questions of public health and safety.

The selection of a site for an atomic power plant is not governed by rules of law, but calls for the application of expert judgment by professional engineers. It is a problem involving great responsibility and technical complexity on which the available knowledge is relatively limited.

Although the criteria for the selection of a site for a conventional type of power plant correspond to well established principles based on the operating experiences of many similar power plants in all parts of the country, the introduction of atomic energy for the generation of electricity has brought with it new criteria for site selection. It will be shown that some of the criteria employed in the selection of the site for the atomic power plant in the case before this Court violate the traditional principles of responsibility which the engineering profession is expected to observe. The basic issue, therefore, although it here concerns specific parties, is of deep concern—now and for all future time—to professional engineers.

It is the belief of amicus curiae that an exposition on the responsibilities of the professional engineer in relationship to the tremendous perils involved in the application of a new science will help to clarify the fundamental questions before this Court. This brief, therefore, represents an effort on the part of a professional engineer to meet his obligations in serving the public interest.

Questions Relating to the Project

The questions before this Court relate to an atomic power plant (Enrico Fermi) currently under construction by the petitioner, Power Reactor Development Company (PRDC), at a site known as Lagoona Beach, some 29 miles southwest of the city of Detroit, Michigan. Although a specific project is here involved, the issues are of overriding importance and applicable to all atomic power developments, whether owned privately or by public bodies.

Why is there a conflict? This question is discussed in considerable detail in the present brief, but the following basic factors are elements in the conflict:

1. In the selection of this power plant site, the normal influences of professional engineering responsibility for the protection of the public—and the ethical obligations of the engineering profession—have been defined their normal freedom of action.

2. Once the atomic power plant goes into operation, the surrounding population (although generally unaware of its position) would be living in the shadow

of a potential disaster of unprecedented magnitude. For this reason part of the population in the vicinity is seeking relief from the Court to prevent this project becoming an operating hazard.

3. In the event of a major accident or failure of the atomic energy unit, most of the resulting cost of the disaster would fall on the taxpayers of the country. At present they are generally unaware of this potential new burden.

4. In applying for a license for this new power plant (which was approved by the Atomic Energy Commission) some unusual procedures were introduced.

a. A first license has authorized only the financing and construction of the power plant, on the strength that this involves no atomic operating hazards; however, the magnitude of such potential hazards was recognized.

b. A second license for the operation of the power plant is to be considered some years later, after the large capital investment has been made. This sequence may create an element of pressure for gaining approval from those who must finally pass on questions of safety in the operation of this plant.

QUESTIONS BEFORE THE COURT

1. Does the Atomic Energy Act of 1954 require the Commission to withhold approval of a site for an atomic power reactor near a populous area, unless the Commission finds that there are "compelling reasons" for approving such location?

2. Before granting a permit for the construction of a developmental atomic power reactor, is the Commission required, under the Atomic Energy Act of 1954, to determine that the proposed reactor can also be operated at a proposed location without undue risk to the health and safety of the public?

SUMMARY OF ARGUMENT

1. The fundamental question is this: In the experimental or commercial application of a new scientific discovery of an extremely dangerous type, is adequate protection being provided for the health and safety of the public?

2. In the normal course of our historical development the health and safety of the public have been safeguarded by two basic influences which have grown up as intrinsic features of our social and economic system and of our Constitutional form of government. The first influence is a broad structure of law which has been enacted at the local, state and national levels of government; this is administered by selected public officials and is upheld by a distinguished profession in law, as well as by an independent judiciary at each of these levels. The second influence is an equally broad structure (at the local, state and national levels) of trained specialists in the professions of medicine and engineering; these carry out their responsibilities within the law, but with the added obligation of observing the self-imposed disciplines and ethical standards of their professions. Both of these influences are the product of centuries of experience in human relations and mutual confidence.

3. The new scientific discovery of atomic energy is of fundamental importance and far-reaching influence throughout the world. However, its complexities are understood by an extremely small number of scientists; further-

more its application in the useful service of man (for the production of electricity) is generally regarded as being only in the experimental stage.

4. The case before the Court raises some basic questions regarding the application of atomic science under a very limited structure of new land and in conflict with the established disciplines and ethical standards of the engineering profession. This is the first case of its kind before this Court concerning the administration of such law and the final decision will have an important bearing on the future trend in the application of this new science.

5. An objective of this brief is to demonstrate that the present issues before the Court have developed out of various current deficiencies in our social and economic system, and out of the abandonment of the normal sense of responsibility in the application of a hazardous new science.

6. The application of atomic science for the production of electricity ("atomic power") has developed under unique circumstances as a result of an historical coincidence. Scientists succeeded in making the first experimental demonstration of nuclear fission in the same year that World War II began. The destructive potentials of nuclear fission were soon recognized, and this led to the rapid development of the atomic bomb. All of this work was done under governmental control and in strictest wartime secrecy. With the end of the war came a strong desire to apply atomic energy to beneficial uses and, as a first step, Congress passed the Atomic Energy Act of 1946. However, this Act established atomic energy as a government monopoly and subjected the research and development work on such applications to full governmental control. Some eight years later new legislation was enacted (in 1954) which relaxed the governmental monopoly features—but did not eliminate them.

7. In general, the development of atomic power has taken place in a direction opposite to that which has occurred in the production of electric power from coal, oil or falling water. These conventional power sources have grown up step by step through a multi-centered process of development, and under exacting standards of design which carry the approval of the engineering profession. Governmental controls have been devised as the need developed. In contrast, the current development of atomic power is taking place in reverse sequence, starting with the status of a government monopoly. This is interfering with the application of the established disciplines and responsibilities of the engineering profession for safeguarding the public health and safety.

8. In the case of the atomic power project before this Court, if the location of the project had been established within the normal disciplines and responsibilities of the engineering profession, the present site could not have been approved. When an Advisory Committee originally reviewed the proposal, it found the available information insufficient to give assurance that the reactor could be operated at this site without public hazard. Unfortunately, the opinion of this Committee did not prevail.

9. The historical development of law at the state and local levels which, in essence, holds individuals and companies responsible for any damage which their activities might inflict on the public, has produced nationwide standards of public safety. As a concurrent influence, the insurance industry has demanded high standards of safety and the application of sound engineering practices as a prerequisite to writing insurance against any liability which might arise. In the new and startling developments of atomic power the insurance industry was confronted with many new problems and potential hazards of un-

known magnitude. Estimates released by the Atomic Energy Commission revealed that property damage from the failure of an atomic power plant could amount to more than $2,000,000,000, that fatalities could number in the thousands, and injuries in the tens of thousands. The insurance industry sought to serve this new area of risk-taking, but found it beyond its capabilities. The various companies finally pooled their resources and agreed to provide up to $60,000,000 in public liability insurance for an atomic power plant. Although this was an unprecedented amount for the American insurance industry, it fell far short of protecting the manufacturers and the agencies which might engage in the production of atomic power.

10. It must be viewed with regret that this problem was resolved by placing on the Federal Government and, thus, on the nation's taypayers, the liability for any damages (in excess of the amounts covered by the insurance companies) which might result from an atomic power plant disaster. This did not, of course, eliminate the hazard; it only relieved the agencies which might engage in the development or production of atomic power of the great financial responsibilities in the event of a disaster. This is the situation which applies today to all large atomic power projects.

11. The developmental and design programs of the past 15 years, together with operating failures which have occurred on small scale "pilot" atomic power plants, have confirmed the terrifying potentials of disaster which may be associated with such power plants.

12. It is generally recognized that the conventional energy resources of coal, oil and falling water are more than adequate to meet the foreseeable power needs for the remainder of this century. This removes the concept of urgency for generating electricity from "atomic fuels," or of taking chances which involve potentially disastrous consequences (no matter how remote they may be "believed" to be) on the grounds that by so doing the development of atomic power would be "accelerated."

13. The idea that history tends to repeat itself may find some confirmation in the present case. In 1929 the late Lord Chief Justice of England, Hewart of Bury, wrote in eloquent terms about the emergence of a new system of law. He called attention to the trend (in this age of technology) of transferring great responsibilities, by legislation, to new administrative agencies; these, in turn, are given wide range of authority to establish administrative controls and regulations which eventually become "administrative laws." This, he warned, may eventually lead to "administrative lawlessness." Such a trend, obviously, would contain hidden dangers to our Constitutional system of government and to the Rule of Law, as well as to the independence of our established system of justice.

14. The factors and relevant issues involved in the present care are much broader and far-reaching than the simple question whether a specific atomic power reactor should or should not have been constructed at a particular site. The Court's decision in this case could have a far-reaching influence in preventing the abandonment of principle for expediency.

ARGUMENT

I. OBJECTIVE OF THIS BRIEF

The objective of this brief is to demonstrate that:

I. The present issues before the Court have developed out of one or more of the following deficiencies:

(a) Circumvention of the responsibilities of the independent professional engineer;

(b) harmful exploitation of engineering responsibilities;

(c) harmful exploitation of public confidence in the engineering profession;

(d) failure of leaders in the engineering societies to defend the position and responsibilities of the profession;

(e) failure of leaders in higher education and in scientific societies to provide effective interpretation of this new science to public authorities and to the professions;

(f) overzealousness and uncontrolled pressures to manufacture and sell new types of atomic equipment;

(g) undisciplined efforts to excel in new technological achievements:

(h) abandonment of management and corporate responsibilities (as a consequence of special legislation), and transfer of such responsibilities to the Federal Government;

(i) unwillingness or failure on the part of those in high governmental authority to seek or accept responsible engineering advice;

(j) a combination of these deficiencies which may be summarized as "a situation peculiar to these times of declining self-discipline and morality."

II. These deficiencies have led to a situation which is harmful to the public interest and the national welfare. The various areas of responsibility which are involved in the development and practical application of the new science of atomic energy will be reviewed in greater detail.

II. A CONFLICT OF RESPONSIBILITIES

A factor contributing to the present case is the lack of common understanding regarding the basic difference in responsibilities as between scientists and engineers. As a matter of fact, in recent decades there has emerged such a confusing concept of these two professions that the terms "scientist" and "engineer" are at times used interchangeably or in combination as "engineer-scientist." Such a confused use of these designations is harmful to public safety as well as to national policy.

Technology During World War II

World War II was largely a terrifying struggle in the application of modern engineering and science; in the course of this struggle, our nation mobilized its resources of engineering and of science into a single collective "force of technology."

The end of the war left the world disrupted at all levels of civilized endeavor. From this chaos new levels of authority and responsibility had to be established

either through the exercise of dictatorial powers or by the slower processes of democracy.

In this historical transition from war to peace the normal areas of responsibility as between the scientist and the engineer have not been re-established on a basis which would best serve the national welfare. As a matter of fact, the traditional concepts in such matters have become obscured within both of these great professions, and there is little evidence that their members have the resources or the will to redefine their respective areas of responsibility. This must be regarded as a basic defect in our national posture. Furthermore, it can be shown to be a factor in the conflict which this Court has been asked to resolve.

The Decisive Powers of Modern Science

Modern science has demonstrated that it can open the way to a golden age if it is developed in freedom for the benefit of mankind. However, as some of the basic forces of science are becoming all-powerful, modern science is also providing the means for a "reign of terror" under the threat of "total destruction" if these forces are concentrated in the hands of the few and directed toward selfish or ruthless ends. The history of mankind has been a story of being buffetted by the forces of good and evil. Today, more than ever, the choice of direction for the future of man depends upon the wisdom of great decisions involving the application of scientific principles.

One of the great truths of our technological age has been stated in these words: "Modern science is the blessing and curse of our age; it holds decisive powers for good and for evil." Today the ability of man to govern himself—to control his own destiny—has been seriously challenged.

Professional engineers, working in freedom, have a primary responsibility of making plain to their governments, their fellow citizens, indeed to all mankind, the true nature of this situation and of the awesome choices it presents. In meeting this obligation it is their duty to give overriding consideration to the public safety and to the national welfare. This is a moral responsibility—a moral responsibility for the direction taken by our civilization and for the sort of lives our children's children shall inherit.

Definitions of "Scientist" and "Engineer"

There is as much difference between the roles of the scientist and of the engineer as there is between night and day. Specifically, the scientist makes things known and the engineer makes things work. A world-renowned scientist has identified the fundamental characteristic of a scientist by saying that "the most common activity in which a scientist finds himself is to make mistakes, recognize them and correct them."[1] In other words, out of the repeated failures in a research project the skilled scientist eventually brings forth a new discovery. This is the ultimate objective of a scientist. His training has prepared him to become an expert in experimenting; however, no matter how great the public esteem may become as a result of his discovery, he has not become vested, overnight, with any peculiar authority to decide on its use.

Too many scientists, if they succumb in later years to the temptation of assuming administrative or governmental authority, are prone to experiment also in public affairs and to commit monumental errors.

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1 "What Is Scientific Education?" (Dr. Edward Teller) Address presented at Marquette University, Milwaukee, Wisconsin, May 20, 1959. Unpublished transcript from Marquette University.

In contrast, the engineer is trained and disciplined not to make mistakes. He commits himself to the severe discipline and moral obligation of applying scientific principles within established rules of public safety and with due regard to economy and the national welfare. Within these severe demands on personal integrity the professional engineer undertakes to synthesize a wide range of technical, legal, financial and social requirements and to function as a planner, designer, builder or administrator. However, it must be remembered that the application of scientific discoveries remains the task of fallible men and, once the engineer has made a serious mistake, his professional standing may be damaged or permanently ended.

The engineer's conservatism and sense of responsibility in the practical application of scientific discoveries has, in the past, taxed the patience of many a scientist. If left to his own devices and to his "privilege of making mistakes," the scientist is inclined to adopt "short-cuts" in approaching his objectives, and to by-pass the moderating influence and professional disciplines of the engineer. A statement by a noted scientist regarding the post-war development of atomic energy is an example of this philosophy: "This simultaneous pursuit of programs of research, development and construction has become standard in the fast-moving field of atomic energy."[2]

In recent decades the distinctive functions and responsibilities of the professional engineer have become so obscured that a detailed exposition is needed here to identify some of the important elements, particularly as they apply to the conflict before this Court.

The Role of the Professional Engineer

The purpose of engineering is to serve mankind; this service is achieved through the individual and personal responsibility of the professional engineer. His professional services demand every bit as much personal attention and responsibility as that of a surgeon performing a highly critical operation.

Although a professional engineer may rise to a high position of success and public recognition for his achievements, there is, unfortunately, a general lack of understanding and appreciation of the great risks and personal responsibilities which he assumes in his work. Too often this part of the engineer's function comes to public attention only in the event of a failure. Numerous failures have occurred in the past, generally with tragic consequences to the engineer.

As an example, a disastrous failure in engineering occurred on the night of March 12, 1928 when the St. Francis Dam in California broke, resulting in 700 houses being swept away and a loss of 450 lives. The Chief Engineer who was responsible for the design and construction of this dam, Mr. William Mulholland, after 40 years of leadership in his profession, declared: "Don't blame anybody else. Whatever fault there was in this job, put it on me. If there were any errors in judgment—and it's human to make mistakes—the error was mine. I envy only those who are dead."[3]

There is no substitute for such a concept of responsibility in engineering. This sense of personal responsibility on the part of each engineer is particularly important in areas of general public service, such as electric power supply or municipal water supply. Adequate protection of the public health and

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[2] Brief For the Petitioners. United States and Atomic Energy Commission. No. 454, This Term. p. 45.

[3] Western Construction News. Quoted in editorial. San Francisco, California. Vol. III, Number 7, p. 223. April 10, 1928.

safety calls for a nationwide resource of engineers who are dedicated to the practice of their profession in accordance with established disciplines and ethics. Such engineers have the obligation of building and operating public and private facilities of all types which conform to approved standards of design and economy and which contribute to the advancement of the nation within our Constitutional form of government and within the established rules of law.

It is in these terms that the engineering profession is a vital national asset whose members are skilled in applying scientific discoveries for the benefit and well-being of the public. Unwarranted political influence or encroachment on their responsibilities and authority would clearly be a violation of public trust.

Thaddeus Merriman, the former Chief Engineer of the Board of Water Supply for the City of New York has summarized the professional engineer's obligations as follows:

> ". . . [The engineer's] duty does not lie only in saving a maximum of his client's money. It demands absolutely that the public be afforded a maximum of safety. If the client is unwilling or unable to pay for that maximum then he should not have [his project]. And what is true in the case of a private client is just as importantly true when the engineer acts for public authority—he must still protect the public—no one else can perform that function."[4]

The sense of responsibility of professional engineers, together with the confidence of the public in the engineering profession, comprise a rich heritage which stands as the primary bulwark for the protection of the public in the application of science and technology. This confidence must be maintained and merited in the future as an essential feature of a free society. The public has a right to expect absolute intellectual honesty. Herbert Hoover has stated most precisely that "technology without intellectual honesty will not work."

The Importance of Freedom in Engineering

It has been well stated that: "Without engineering, freedom could bring you a happier but not an easier life. Without freedom, dictators could use engineering to enslave you."[5]

Without freedom the professional engineer is unable to meet his ethical obligations in the practice of his technical skills, and without freedom, he is unable to serve his client's and the public's interest to best advantage.

A noted engineer has described the obligations of the professional engineer in these terms:

> "Since engineering is a profession which affects the material basis of everyone's life, there is almost always an unconsulted third party involved in any contract between the engineer and those who employ him, and that is the country, the people as a whole. These, too, are the engineer's clients, albeit involuntarily. Engineering ethics ought, therefore, to safeguard those interests most carefully. Knowing more than the public about the effects his work will have, the engineer ought to consider himself an officer of the court and keep the general interest always in mind.

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[4] "Naught But the Best," by Thaddeus Merriman, Civil Engineering, December 1939, pp. 701-702.

[5] Inscription on Museum of Science and Industry, Chicago, Illinois.

> "Service ceases to be professional if it has in any way been dictated by the client or employer. Professional independence is not a special privilege but rather an inner necessity for the true professional man and a safeguard for his employers and the general public. Without it he negates everything that makes him a professional person and he becomes at best a routine technician or a hired hand, at worst, a hack."[6]

In recent years decisions have been made in areas of science—areas in which even the well educated man is often a stranger—which affect the lives and welfare of many people and of entire nations. However, if a free society is to remain free, it must demand the application of scientific discoveries under the dedicated responsibility of professional engineers working in freedom.

Responsibilities and Limitations in Engineering Design

The predominant influences of science and of engineering have appeared on the world's scene within the past century, which, in terms of history, is a relatively short time. The turn of the century marks the beginning of the revolutionary period of modern science, and it is still within the span of our lifetimes that engineers have become a vital factor in the American industrial scene. Not long ago industrial development depended largely upon mechanical inventiveness. With the advent of modern science have come discoveries and explanations which are more fundamental. Yet, such fundamentals do not explain what is engineeringly sound.

With the advent of a new science the engineer cannot minimize or ignore a potential hazard on the grounds that all of the scientific data necessary for a complete understanding of the hazard are not available. In fact, it is precisely in such areas where the professional skills and judgment of the engineer take on added importance as a moderating influence.

Recognizing that error is an inherent factor in all human activity, the professional engineer applies his technical knowledge and professional disciplines preponderantly on the side of safety. One of his most important tools is the "factor of safety." For example, the stability of a dam may have a factor of safety of 2; this means that before such a structure would fail, the supported load would have to be twice the assumed or predictable load for which the structure was designed. Thus the factor of safety compensates for unexpected or unpredictable greater loads in the coming decades, as well as for possible deterioration with time.

The factor of safety has also been called the "factor of ignorance"—as an acknowledgment of the inability to predict all of the events which a structure may experience in the future. Similar criteria apply in all engineering but, in spite of all the applied skill and precautions, failures continue to occur for many reasons which could not be anticipated in the original design.

There is no such thing as foolproof design or operation of a power plant. The possibility of an accident or disaster is ever present and the biggest disasters have been the most incredible. Generally, out of a painstaking investigation of a disaster a complex chain of "incredible" circumstances has emerged to explain the cause.

Modern history records numerous disasters in engineering and technology, with tragic loss of life, such as the sinking of the "unsinkable" Titanic, the conflagration in the "fireproof" Iroquois Theater, the explosion of gas in the new school of New London, Texas, the collision of two large passenger air-

[6] The Meaning of Your Profession." 104 Cong. Rec. 18349, 18351.

planes over the vast expanse of the Grand Canyon region. Many others could be cited. In every case there was a great loss of life and property. And in every case the odds against the occurrence were undoubtedly considered to be fantastically large. Nonetheless, they did occur and there is no reason to believe that others will not occur in the future.

Separation of Responsibilities of Engineers

The personal responsibilities of a professional engineer are at times so great that it is in the best interest of all concerned to subdivide and isolate the main areas of engineering responsibility, and to adopt a system of checks and balances similar to the system of our republican form of government.

For example, a project may be undertaken by a corporation whose chief engineer has the primary responsibility of interpreting the particular objectives as laid down by his directors. (This would correspond to the legislative branch of our government.)

A second area of responsibility is undertaken by a separate consulting engineer and his firm which create the designs within economic limits and under approved factors of safety; this firm would also supervise the interpretation of its designs during the period of construction and during the manufacture of the required machinery and materials. (This would correspond to the administrative branch of our government.)

A third area of engineering responsibility rests on the shoulders of the chief engineer for the contractor who undertakes the construction of the project for a specific price. His primary obligation is to devise the most efficient and economical construction techniques in full compliance with the plans and specifications. (This would correspond to a second area within the administrative branch of government.)

A fourth area of engineering responsibility is assigned to an independent consulting engineer (or to an independent board of consulting engineers), with the overriding duty of looking after the owner's and the public's best interests, by acting as an observer or technical auditor during the planning, design, financing and construction of the project, and in reviewing issues which may run into conflict. (This would correspond to the judicial branch of the government.)

Such a system of coordinated professional controls, functioning freely, but, without compromise on important professional responsibilities in each of the four areas has, in the past, produced notable engineering achievements; more importantly, it has effectively minimized the occurrence of serious mistakes or failures in the administration and execution of the work.

Unfortunately, in recent years this system of control of engineering responsibilities has been displaced all too often by political domination of such controls. In other cases the so-called "more efficient package deal" system of contracting has been offered in which the constructor or even the manufacturer of power plant equipment undertakes to provide all of the services, not only of construction and manufacture of the equipment, but also the engineering planning and design, with the engineers appearing in direct partnership or as sub-contractors. It is inevitable that in such cases the independent professional control of major engineering responsibilities (in the best interest of the client and the public) is obliterated and displaced by the motivations of easier profits for the constructor or the manufacturer. In some cases this has led to very faulty engineering planning and construction, or in other cases to

scandalous performances in diverting and wasting public funds even though the design and construction may have been of good quality.

III. UNIQUE HISTORICAL FACTORS IN ATOMIC POWER DEVELOPMENT

The unique circumstances under which atomic power has been developed appear to be largely the result of an historical coincidence. In 1939 experimental demonstration had been made of the phenomenon known as nuclear fission. This same year also saw the outbreak of World War II. When it became evident that this newly discovered phenomenon might be applied to the fabrication of a weapon with unprecedented destructive power, the subject of nuclear fission (atomic energy) became a "top secret" high priority program under strict military control. This program was almost totally concerned with the development of a new type of bomb. Destruction was the primary objective; cost was of secondary concern. The terrifying demonstration of the atomic bomb's power in 1945 removed all doubts regarding the outcome of this wartime project.

With the advent of the fearfully destructive power of the atom has come a universal hope that eventually this power would be harnessed for equally impressive purposes, in the service of mankind. Unfortunately, however, this hope has been permitted to grow, through excessive publicity and false propaganda, to a point where the practical realities have become obscured. Once a new scientific concept with revolutionary potentialities has been demonstrated to have a certain "technical feasibility," it is still far removed from economic application.

After the end of World War II the high priority program of atomic energy for military use was modified. This led to the passage of the Atomic Energy Act of 1946 (60 Stat. 755), which established atomic energy as a Government monopoly. A basic factor in this decision (as acknowledged by the Congress in the Act itself) was the inability to predict how, or when, atomic energy could be used for civilian purposes. Accordingly, research and development of atomic power reactors for the production of electricity grew up as a monopoly venture under the control of the Atomic Energy Commission.

As in the case of the atomic bomb, the atomic power reactor also employs the principle of nuclear fission but, instead of suddenly releasing an enormous body of heat by explosion, the power reactor[7] is designed to maintain a controlled release of a limited amount of heat over a long period of time. This controlled heat is delivered to a heat exchanger where water is converted to steam; the steam, in turn, drives a conventional turbine generator for the production of electricity.

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[7] The special type of reactor to be employed by PRDC is called a "breeder reactor." The energy source will be fuel rods of enriched uranium. As these are consumed by fission at high temperature for the production of steam and the generation of electricity, a transformation occurs within the fuel rods and surrounding "blanket"; this results in a phenomenon called "breeding" in which some of the uranium (U-238) is converted into plutonium (Pu-239). Since this plutonium is not expected to be used in this reactor, it will be sold back to the Atomic Energy Commission for other uses.

The term "breeding" applies only to this transformation of materials. It does not infer some kind of "reproductive process" of creating new energy for prolonging the operation of this reactor. The total energy resource which entered the reactor at the beginning of the cycle is, of course, reduced by the amount of heat energy which is consumed for the generation of electricity.

The appropriation of great sums of federal funds provided a major impetus for the atomic power program. Any question regarding soundness of the program was swept aside by a variety of considerations, including: willingness to accept unsupportable claims regarding the great potentialities in the new science; and desire for prestige by being first among the scientists of the various nations with any new developments.

It was not until 1951 that private groups were permitted to undertake limited studies in the application of atomic energy for the production of electricity. Even then, however, such studies were essentially under the complete control of the Commission, and were subject to all of the then prevailing regulations of secrecy and other restrictions.

Continuation of Governmental Controls

Interest continued to develop in the application of atomic energy for civilian purposes, and this led to the passage of the Atomic Energy Act of 1954 (68 Stat. 919). The Act of 1954 was designed, as were subsequent amendments, to permit private industry to employ the new technology in the construction of a limited number of atomic power plants. Despite the relaxation in the governmental monopoly of atomic energy, however, the Government still retains the following functions:

(a) It is the sole producer of enriched material for fuels to be used in power reactors.

(b) It sets the price of nuclear fuel and is empowered to guarantee prices or waive its charges.

(c) It owns and controls many of the basic research centers concerned with atomic energy and the information released therefrom.

(d) It has the power to pre-empt ownership of all patents which pertain to atomic developments.

(e) It is a leading developer of various types of atomic power reactors.

(f) It subsidizes, or has some form of financial stake in virtually all of the atomic power plants, publicly or privately owned, now in operation or under construction.

Limitations in Application of Engineering Responsibility

In retrospect it is quite apparent that the origin and growth of atomic power has followed a reverse sequence to that which has taken place in the development of the conventional sources of power—coal, oil, gas and water. In these compulsive circumstances, the engineering profession is confronted with the question of how to apply its traditional disciplines and responsibilities for public safety to the production of electricity under the following new conditions:

(1) The scientific principles of the atomic power reactor are understood by relatively few scientists, and by very few engineers.

(2) Only limited knowledge is available regarding the reactor's heat-producing characteristics in large quantities and over prolonged periods of time.

(3) An atomic power reactor is known to be a highly dangerous device, and its design and application must be developed with extreme care.

(4) No adequate record of operating experiences is available which might serve as a significant guide for the design of large power reactors.

(5) It is known that a major failure of a power reactor could do tremendous damage to life and property.

(6) The insurance companies are unwilling, in fact unable, to assume the full liability for any major reactor failure, or to protect the owners and operators of the power reactor from damage and death claims following a reactor failure.

(7) The consequences of sabotage or deliberate inducement of a major failure in a power reactor could lead to tremendous damage to life and property; there is no clear prospect of developing a simple design which would protect the public against this contingency.

(8) The ultimate cost of a reactor power plant cannot be satisfactorily predicted and could, conceivably, overrun an estimate two or three times.

(9) It is known that the cost of producing electricity from an atomic power plant is several times greater than the cost of electricity from conventional steam plants. Furthermore, the cost of various items, such as nuclear fuel rods and the disposal of waste, contain government subsidies of unknown magnitude.

(10) From an engineering standpoint there is no economic justification for an atomic power plant.

(11) At best, if investment cost and operating cost were to be disregarded, an atomic power plant may be considered an experimental facility.

(12) The development and control of this new science is in the hands of the Federal Government, and anyone wishing to engage in it may be obliged to work under restrictive regulations and rules of secrecy. This is an unprecedented situation. The conventional and traditional atmosphere of freedom of exchange of knowledge among engineers does not prevail.

(13) There is no indication that a system of checks and balances in engineering responsibilities prevails in this new field.

(14) No legal structure within the accepted principles of the "rule of law" and the Constitution of the United States has been established with respect to this new area of science. (See comments on Rule of Law, infra pp. 53-54.)

IV. BASIC PROBLEMS IN POWER PLANT LOCATION

Electric energy is produced for the benefit of the consumer. It has the unique characteristic of portability by means of transmission lines, and where it originates is of no direct concern to the consumer. Hence, there is considerable freedom of choice in the location of generating (or power) plants. As a first step, and for comparative purposes, the criteria which generally govern the location of the conventional types of power plants are presented.

Choice of Location of a Thermal Power Plant

A coal-burning steam power plant may be located either at the mouth of a coal mine or adjacent to an industrial load center, the choice depending on whether it is more economical to transmit the electricity or to transport the coal between the mine and the load center. An oil-burning steam plant is usually located near the load center, because of the ease and economy of transporting oil in pipelines.

The detailed choice of location of the power plant and related fuel storage, and the detailed design of the high-pressure steam boilers and all other components, is dependent upon well established engineering criteria which, in turn, are based on long records of experience in the operation of similar power plants throughout the country. Such engineering decisions must also meet the ap-

proval of the insurance underwriters. This system of control of the safety features in design and location of thermal power plants has evolved from the free interplay of opportunity and responsibility brought about by private or local initiative, tested by experience, generally governed by sound economic considerations in their application and, as the need arose, subject to regulatory controls by public utility commissions.

Another basic influence in this process of engineering development has been the record of failures and disasters in earlier power plants. It is part of the history of engineering that many of the most important advancements in the art have been developed from the lessons learned through the occurrence of major failures or disasters. Such failures obviously were not expected to occur. However, whenever they have occurred, the resources of the engineering profession have been mobilized to identify their cause and to establish modifications in engineering practice which have helped to prevent their recurrence. This is part of the slow and difficult process by which the art of engineering advances step by step and with due regard for the public's safety.

Choice of Location of a Hydroelectric Power Plant

There is less freedom of choice with respect to the location of a hydroelectric power plant. It must be located where a river has a site which is favorable to economic development. Such a location may be hundreds of miles distant from the load centers, and the electric energy must be conveyed over long transmission lines to the consuming areas.

Choice of Location of an Atomic Power Plant

The possibility of a serious reactor failure introduces some overriding considerations in any decision involving the location of an atomic power plant. The failure of a reactor, which involves the release of radioactive material to the atmosphere, can inflict terrifying damage on the property and on the population which may be located in the vicinity. The magnitude and extent of such destruction will be discussed later in greater detail.

Furthermore, the operation of an atomic power reactor introduces some new problems with respect to waste disposal. Reactor waste products are highly radioactive and so dangerous that they must be permanently stored in inaccessible places. These problems have been solved only to a limited degree. At present there are no economical solutions available, and, or course, no experience to guide the engineering profession in this new area of responsibility.

Under these circumstances a professional engineer might undertake the design of an experimental atomic power plant of limited size and cost and apply the highest degree of skill and judgment to the design of all its elements. However, there would still remain the overriding problem of locating this new power plant so it could not become an undue hazard to public life or property.

The solution which could be regarded as most acceptable by responsible engineers would be to construct such a power plant at a remote location and within a cavern excavated far back in a solid rock formation; as in the case of many hydroelectric developments, the electrical output would be delivered over long transmission lines to the load center. This concept of design was actually developed by some of the world's most competent engineers and has been adopted as a requirement in some other parts of the world. It was assumed that, in the event of any major failure of the nuclear reactor, the passageway to the cavern would be permanently sealed off and the project could be abandoned, without having exposed life or property in the vicinity to harmful radioactivity.

A Failure in Professional Engineering Responsibilities

In the case before this Court, as will be indicated in greater detail, it is a regrettable fact that the conventional responsibilities of the professional engineer, and his overriding obligations to the public safety, have not been fully respected. Furthermore, the essentials of professional freedom and moral duty to serve the best interests of the public and of the country did not prevail. If professional freedom had prevailed, it is most probable that the project now being contested before this Court would not have been constructed at the present site.

Hence it must be said of this project that the choice of location is the result of a denial of professional freedom, and of a terrifying violation of engineering disciplines and ethics. To support such a broad declaration requires an examination of the circumstances which led to the choice of the present location, and of the evidence which was available at the time regarding the potential hazards to the public.

If a remote location actually was recommended (as representing the best judgment of an independent consulting engineer), there is no evidence that such an opinion was considered acceptable, or that such independent and responsible judgment was invited. Furthermore, there is no evidence that the engineering profession publicly protested this violation of its professional disciplines and its stature before the public. The net result was that those responsible for construction of this project made the deliberate choice of a site in the vicinity of two large cities. The apparent reasons for this choice are without precedent and must be regarded as historically incredible. These are the basic issues which have brought the present case before this Court.

V. CRITERIA FOR SAFETY AND PUBLIC HEALTH

It is noteworthy that in all engineering, the criteria for design, or for the protection of health and safety, have of necessity been established in advance of full understanding of the related scientific principles. Much remains to be learned in all areas of engineering; this applies particularly in the area of public health. In this area the factor of safety has always been large and in favor of the public.

To cite a specific case, the supply of safe drinking water in every locality is an example, on a nationwide scale, of applied disciplines in engineering. The American system of water supply may truly be called a miracle. The continuity of such a standard of service demands constant vigilance and attention to many details on the part of thousands of engineers and employees in water works. Certainly, no one would advocate a lower standard of safety in water supply for the sole purpose of saving some money. It would be considered preposterous if a public official were to advocate a lower factor of safety and cheaper, water supply on the premise that the community would be financially ahead, even if this were to result in an occasional contamination of the water—or outbreak of typhoid—or a "slight" rise in the death rate.

Criteria for Radiation Limits for Human Beings

> "It is only with research for criteria for radiation limits that one finds suggestions that it should be permissible to kill people to attain benefits to society. This has undoubtedly been in the minds of all criteria makers,

but rarely has it reached the frank and stark pronouncements of recent years."

Thus testified one of the most competent living authorities in the field of sanitary engineering before the Joint Committee on Atomic Energy in 1960.[8] He continued:

"Fear has been expressed that the establishment of too rigid criteria for the radiation activity may stifle progress because of excessive costs of attainment. One may view this fear with some cynicism in the light of the whole history of health and safety endeavor. This fear has always been expressed, but the historical realities consistently bely it. Criteria must rest upon health protection and not cost.

"No one, of course, should advocate excessive and unnecessary restraints. Those restraints most logically suggested, however, within the framework of current scientific understanding should not be resisted solely because resulting costs may threaten to throttle application. This should be scrutinized with a great deal of care before it is accepted as a base line of decision.

"The radiation field is today confronted with similar problems and decisions, greatly complicated by the very nature of the biological effects to be considered. The effects of radiation are unclear and not fully predictable with assurance, perhaps for some years. Yet one cannot bide one's time in placing restraints upon the public and private producer. These latter do not have an unblemished record of self-policing. Hence society must look to scientific groups and public officials for providing criteria and guides, at times admittedly uncertain, and others admittedly tentative. As knowledge increases, reappraisals ensue, either for relaxation or for tightening of criteria. These supposedly fumbling steps have much historical validity and precedent in public health practice. . . .

"The day of handbook rule for measuring the hazards of radiation is a long way off. In the meantime one acts upon limited knowledge. In such action the guiding principle must be the maximum protection of the people, not because of sentiment but because society demands it. An agreed acceptance of a number of consequent disabilities is not an appealing basis for the development, say, of nuclear power. Industry will do better than rest upon such an affront to man. I know they will, and have."

VI. REPORT OF ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

The problem of appraising the safety aspects of the Lagoona Beach project under "the guiding principles of maximum protection of the people" was assigned to an independent committee of scientists and engineers known as the Advisory Committee on Reactor Safeguards (ACRS). On June 6, 1956, this committee reported to the Atomic Energy Commission that it had reviewed the

8 Hearings on Radiation Protection Criteria and Standards: Their Basis and Use, before Joint Committee on Atomic Energy, 86th Cong., 2d Sess. pp. 29–45.

application of PRDC and had come to the conclusion that it could not approve the application.[9] Quoting from the report:

> "The proposed PRDC reactor represents a greater step beyond the existing state of the art than any other reactor of comparable power level which has been proposed by an industrial group."
>
> "From this review the following conclusions were derived:
>
> 1. "Even though there are no facts or calculations available to the committee that clearly indicate that the proposed reactor is not safe for this site, the committee believes there is insufficient information available at this time to give assurance that the PRDC reactor can be operated at this site without public hazard."
> 2. "It appears doubtful that sufficient experimental information will be available in time to give assurance of safe operation of this reactor unless the present fast reactor program of the AEC is amplified and accelerated as detailed below.
> 3. "It is impossible to say whether or not an accelerated program would give sufficient information to permit safe operation of this reactor at the Lagoona Beach site on the time schedule presently proposed."
>
> "The Committee considers it important that bold steps be taken to advance the development of the fast breeder reactor concept and commends the willingness of the Power Reactor Development Company to risk its capital and prestige in advancing the development of this reactor concept. But the Committee does not feel that the steps to be taken should be so bold as to risk the health and safety of the public. It is important for the AEC to provide sufficient development facilities and experimental information that the safety aspects of the PRDC reactor can be reliably appraised in advance of operation of the reactor itself."

Unfortunately, this report was withheld from publication and the conditional construction permit was authorized by the Commission on August 4, 1956. The report finally was released on October 9, 1956.

Questions Raised by Joint Committee on Atomic Energy

A major difference of opinion regarding this report developed between the Chairman of the Congressional Joint Committee on Atomic Energy and the Chairman of the Atomic Energy Commission.

On August 4, 1956, the Chairman of the Joint Committee issued a statement containing the following:[10]

> "AEC has informed the Joint Committee on Atomic Energy that it has issued a construction permit to PRDC of Detroit to construct a nuclear power plant near Monroe, Michigan. This is known as the Detroit Edison reactor.

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9 "A Study of AEC Procedures and Organization in the Licensing of Reactor Facilities," Joint Committee on Atomic Energy, 85th Cong., 1st Sess. (Joint Committee Print 1957), p. 133.

10 Joint Committee on Atomic Energy, Supra note 9, pp. 125-126.

"The issuance of this construction permit, in my opinion, sets a dangerous pattern in the early stages of AEC regulative and quasi-judicial activity for the following reasons:

"1. The AEC has issued this permit as a result of 'star chamber' proceedings in which the report of its Advisory Committee on Reactor Safeguards, which raised grave doubts as to the safety of the proposed reactor, has never been made public by AEC. It is my understanding that this important report, filed on June 6, 1956, which was prepared by a distinguished committee of experts, has not been retracted or modified by them.

"4. From a practical standpoint, AEC might feel obligated to go on through with a bad deal with respect to public safety because they will have permitted the expenditure of huge sums under the construction permit. It is my belief that decisions on safety should be made without any examination of dollars involved but only from the standpoint of human lives."

VII. PROBLEMS OF INSURABILITY

Traditionally the power industry has developed under laws which, in essence, hold the individual power companies responsible for any damages which their activities might inflict on the public. This concept of liability has proven to be a strong influence upon the industry in developing its high record of safety. As a result, new scientific and technological developments have been adopted only after undergoing severe tests, and after adequate proof that the adoption of any new equipment would be consistent with the prevailing standards of safety.

A vital factor in this process has been the private insurance industry. For example, as boilers for steam power plants have increased in size and output, it has taken many decades to develop the responsible criteria of design under the constantly increasing temperatures and steam pressures. In such details as the metallurgy of the steel, welding and fabricating procedures, installation, operating controls, and safety devices, the great traditions of responsibility in engineering and in manufacturing have served as a foundation for taking each progressively higher step. In all of this development the insurance industry has participated with clear understanding of its responsibilities, and has insisted on the application of sound engineering disciplines before it would assume the liability for public damage due to explosions or other accidents.

In the atomic power field, on the other hand, the insurance companies were confronted with a new peril in which experience is almost totally lacking. At the same time they were confronted with demands for coverage of unprecedented magnitude. After considerable study the private insurance industry was obliged to announce that it would be unable to offer satisfactory public liability insurance on atomic power installations. The position of the private insurance industry was summarized in a comprehensive report from which the following is quoted:[11]

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11 Hearings on Governmental Indemnity before Joint Committee on Atomic Energy, 84th Cong., 2d Sess. pp. 248-250.

"The hazard is new. It differs from anything which our industry has previously been called upon to insure. Its potential is still unknown and must therefore be calculated currently in terms of a body of knowledge which is expanding from day to day.

"Very few insurance companies have had any opportunity to develop first-hand knowledge of the problems involved because of the present limited scope of operation. By the same token, very few insurance companies have developed trained technical personnel to assist their underwriting personnel in insurance evaluation of the hazards involved.

"The catastrophe hazard is apparently many times as great as anything previously known in industry and therefore poses a major challenge to insurance companies. . . . We have heard estimates of catastrophe potential under the worst possible circumstances running not merely into millions or tens of millions but into hundreds of millions and billions of dollars. It is a reasonable question of public policy as to whether a hazard of this magnitude should be permitted, if it actually exists. Obviously there is no principle of insurance that can be applied to a single location where the potential loss approaches such astronomical proportions. Even if insurance could be found, there is a serious question whether the amount of damage to persons and property would be worth the possible benefits accruing from atomic development."

Catastrophe Hazards

In addition to the damage to the power plant and operating personnel from a conceivable accident in an atomic reactor, the far greater hazard lies in the radiation exposure and contamination which could occur if the fission products should be released to the surrounding area. It is conceivable that accidental atomic or chemical reactions within the reactor or auxiliary systems could destroy equipment, break the containment structures, and release the accumulated fission products to the atmosphere in a highly divided state. Once airborne, these toxic products could be widely dispersed, threatening the health and safety of people over wide areas. The danger may be emphasized by noting that some radioactive materials are more than a million times as toxic as chlorine, the most potent common industrial poison.

Naturally, the Atomic Energy Commission, as well as the manufacturers and public utilities engaged in atomic power development, have been deeply concerned over the type and amount of damage to people and property which could occur in the event of a major catastrophe, and with the problems of settling the ensuing damage claims.

In March 1957, the Atomic Energy Commission published a report which is generally known as the Brookhaven Report: "Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants."[12] This report contains the studies of an "assumed condition of accidental failure" of an atomic reactor with an electrical power capacity of 100,000 to 200,000 kw and located on a river about 30 miles from a major city. Various assumptions and conditions of the surrounding region were defined to provide some basis for computation. It must, of course, be kept in mind that some of the problems

12 "Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants." ("Brookhaven Report"), R. 874–917.

involved are extremely difficult to analyze. However, the figures were intended to serve as an "order of magnitude" indication of the possible consequences of a major reactor failure. Such a failure could result in contamination of large areas from deposited fission products. Inhabitants of portions of the areas affected would have to be evacuated to avoid serious exposure. Standing crops would be lost. Agricultural use would be curtailed. Access to various areas would be restricted for considerable periods of time.

The results of these studies indicated that, depending upon the weather conditions and temperature of the released fission products for the assumed accident, the property damage alone could range between $2,300 million and $4,000 million and possibly higher. Damage to health and life could be in the order of 43,000 injuries and 3,400 fatalities, without taking into account the probability of harmful long-term effects on several hundred-thousand people. The financial liability for human casualties was not evaluated and obviously is beyond comprehension.

It might well be wondered, under these circumstances, how any agency engaged in the generation of electricity could afford to undertake the construction of an atomic power plant when faced with the possibility of becoming liable for such vast potential damages.

Government Acceptance of Liability

Eventually the private insurance industry, after pooling all its resources, committed itself to underwriting liability coverage on a single atomic power installation in the amount of $60 million. However, this represents only a small fraction of the potential damage to life and property from a major failure of an atomic reactor.

To resolve this impasse, a proposal was advanced which must be regarded as a great historical tragedy in the affairs of our government. The Atomic Energy Commission chose to recommend to the Congress—and the Congress saw fit to enact—legislation by which the liability, except for the comparatively small coverage provided by the private insurance industry, was transferred to the taxpayers of the nation. The 85th Congress adopted Public Law 85-256, known as the "Price-Anderson Act," which added Section 170 to the Atomic Energy Act of 1954. This Act was approved on September 2, 1957. (42 U. S. C. 2210)

Under this Act the United States Government has assumed a liability which is stated as a maximum of $500 million for each accident. However, in view of the commitment in principle, it is difficult to visualize how the Government could escape a much greater liability in the event of a larger disaster. The possibility of such a disaster occurring, obviously, has been acknowledged by the passage of this amendment. Representatives from the power and manufacturing industries had stated that without such assumption of liability by the government they would not be able to continue their participation in the atomic power program.

The enactment of these indemnity provisions into law, however, has not eliminated the hazard. It has served only to relieve the individual power companies and the manufacturers of the traditional system of financial liability by transferring such liability to the Federal Government. In this manner the way was paved for building so-called "low-cost atomic power plants" near the load centers. Following enactment of the Price-Anderson Act, a number of publicly and privately owned atomic power plants have been undertaken with governmental approval near populous areas, thus subjecting the people, without their

consent, to unnecessary and unprecedented hazards. The ultimate liability in the event of a disaster has been transferred, according to law, to the nation's taxpayers.

The net result of this action has been to circumvent and disrupt the traditional system of disciplines and responsibility of the engineering profession. As has been previously stated, the public has great confidence in the engineering profession to protect the public health and safety, and professional engineers are expected to assume their responsibilities and serve under the highest standards of ethics and intellectual honesty. However, these standards cannot prevail under a system of government indemnity which displaces such responsibilities.

Probability of An Atomic Disaster

It has been alleged that the location of an atomic power plant near a populated area is permissible on the grounds that the many safety precautions taken to avoid an accident render the possibilities of an atomic disaster "exceedingly improbable." However, as noted previously, such assurances in no way alter the fact that virtually every major accident or disaster which has occurred in past history has been "exceedingly improbable."

History has clearly demonstrated that man, with his imperfections, has never been able to foresee all future technical events. Despite his best efforts, failures have occurred; at the same time, he has used these failures to increase his knowledge and widen his range of confidence. In the face of this long-established historical fact, the atomic energy program is currently being promoted on the assumption that a major accident will not occur. However, despite the excellent technical efforts which have been applied to date, such an assumption, particularly in view of the completely new technology involved, must be regarded as utterly unrealistic.

Failures in the Field of Atomic Energy

Although the atomic energy industry is very young and has relatively few installations, it has achieved an impressive record of safety in its brief history. In fact, it seems doubtful that any other industry can show greater concern for safety in terms of time and effort, or money expenditures. However, reassuring as this fact may be, it is also significant that despite this safety effort, failures are still occurring. Such failures range from relatively minor ones to the more serious. In most cases the reactors which have failed have been relatively small. Some of the failures in the operation of atomic reactors have resulted in deaths, or have exposed considerable numbers of persons to radiation.

A failure occurred in December 1950 at the National Research Experiment (NRX), Chalk River, Canada, which resulted in a nuclear runaway and explosion. This accident is not widely known because the security regulations at the time of the incident were very strict; but it resulted in the death of one man and the serious radioactive contamination of five others.[13]

At Windscale, England, in 1957 a fire in an atomic reactor resulted in the widespread release of radioactive material over the surrounding countryside. It fell on the pasture lands of farms in a 200-square-mile area. The cows, while grazing, absorbed the fallout of iodine-131; it reappeared in the milk. Fortunately this was discovered almost immediately by scientific monitoring, and resulted in a ban on the use of all milk produced in this area. It was con-

13 "AEC Experience in Radiation Accidents," by D. F. Hayes. In A Compendium of Information for Use in Controlling Radiation Emergencies." U. S. Atomic Energy Commission. September 1960. pp. 2-3.

sidered advisable to dump all the milk for a period of two months to prevent its consumption by young children who might otherwise have accumulated significant quantities of radioactive iodine in their thyroid glands. The report of the board of investigation stated that the cause of the accident was due partly to inadequacies in the instrumentation provided for the control of operations, and partly to faulty judgment by the operating staff, these failures in judgment being themselves attributable to weaknesses of organization.[14]

Although both of these failures, among a number of others, have occurred outside the United States, published accounts have recorded 39 failures in reactors of various types in this country.

On January 3, 1961, about 9 p. m. a failure occurred near Arco, Idaho, in an AEC prototype power reactor rated at 200 kw. This resulted in the death of three persons who were working on the reactor at the time of the accident. Prior to this failure it was known that a variety of troubles had developed, some having their origin in the design and others in the operation of the reactor. Because of the high radiation levels inside the building, it has not been possible to enter and determine the cause of the failure.

The AEC report of January 27, 1961 states:

> "Because of the high radiation levels, it was not possible to remove the second crewman until January 5, and the third crewman until January 9."
>
> "At this time it is not possible to identify completely or with certainty the causes of the incident. The most likely immediate cause of the explosion appears to have been a nuclear excursion resulting from motion of the central control rod. As yet there is no evidence to support any of several other conceivable initiating mechanisms."[15]

These and other failures provide impressive evidence that no matter how great an effort may be made to prevent them, accidents will occur. This is particularly true in the development of a technology as new as atomic energy—much still remains to be learned.

Steel Containment Vessel

During the early 1950's there was considerable discussion on how to design an unprecedented type of power plant containing an atomic reactor. As a basic principle it was generally agreed that every effort should be made to minimize the hazard to the public as much as possible.

It had been determined that any release of fissionable material to the atmosphere could have a terrifying and disastrous result on public life and property in the vicinity. The possibility of such an occurrence, no matter how remote it might be, had to be admitted. These considerations eventually led to a proposal to construct a steel plate "containment shell" or dome completely surrounding the reactor unit. This dome presumably would confine whatever cloud of fissionable material might otherwise be released to the atmosphere. The dome at the PRDC (Enrico Fermi) atomic power plant at Lagoona Beach

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14 "Accident at Windscale No. 1 Pile on 10th October, 1957." Presented to Parliament by the Prime Minister by Command of Her Majesty, November 1957. Cmnd. 302. London, HMSO.

15 "Interim Report on the SL-1 Incident." Report of the General Manager's Board of Investigation. U. S. Atomic Energy Commission. January 27, 1961. pp. 2, 11.

consists of a steel shell 72 ft. in diameter, 120 ft. high, and with varying thicknesses of steel plate from 0.52 to 1.25 inches.

Such a structure has become a highly controversial design concept and there is a considerable body of professional engineering judgment that it is of extremely limited value in safeguarding the public.

It could be claimed that the design of this dome has had the benefit of a careful review by the United States Naval Ordnance Laboratory in White Oak, Maryland. However, an examination of this report indicates that it does not claim to be a comprehensive treatise on the containment problem for this reactor power plant, and that many of the containment problems that are peculiar to this reactor have never been solved either experimentally or theoretically.

The limitations and reservations noted in this report reveal that the authors and the officers of the U. S. Naval Laboratory recognize the tremendous responsibilities involved in the over-all project. They have stressed the fact that their participation in a limited study area may not be regarded inferentially as approval of many other important areas which have not been studied. This sense of responsibility is in keeping with high professional engineering standards and is worthy of commendation. (It is regrettable that this report has not been given the degree of recognition commensurate with its importance.)

The following quotations from the Abstract of this report indicate the great care with which the U. S. Naval Laboratory approached this problem:

> "A study has been made on the ability of the Enrico Fermi fast breeder reactor plant to contain a nuclear excursion equivalent to the violence produced by 1,000 pounds of TNT. The results of the study indicate that the reactor plant can contain shock waves developed in the air and in the sodium and also fragments from the cylindrical covering materials surrounding the reactor core. The rotating shield plug, however, is a serious hazard when projected by the gun action of the internal blast pressure in the reactor compartment. This problem is analyzed and a recommendation has been made to lessen the danger.
>
> "This report is not claimed to be a comprehensive treatise on the containment problem for this reactor plant. To do so would go far beyond the intended scope of this study. Many of the containment problems that are peculiar to this reactor have never been solved experimentally or theoretically. Conclusions that have been made are based on concepts taken from applicable areas of explosions research.
>
> "It is emphasized that this entire report is based on information furnished by the Atomic Energy Commission that the most probable upper limit of energy release from a power excursion of this reactor is estimated to be 4.54 times 10^8 calories. Within this limitation and others noted here and elsewhere in the text, this report is presented for information purposes."[16] (Emphasis added)

The limited value of the containment shell or dome, from the standpoint of public safety, is particularly understood by those who have some appreciation of the consequences of sabotage or other possibilities of planned destruction.

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16 "Containment Study of the Enrico Fermi Fast Breeder Reactor Plant." U. S. Naval Ordnance Laboratory, White Oak, Maryland. NAVORD Report 5747. 7 October 1957. pp. i-ii.

(Some descriptions of its protective value are reminiscent of the Middle Ages and indicative of the controversial nature of this design concept.)

"Compelling Reasons" Criterion is Sound and Desirable

One of the questions before this Court is whether the Commission must establish "compelling reasons" before it can approve the location of a reactor near a heavily populated area. However, the petitioners claim that this would "seriously impede and, in significant areas, might even block the programs and policies that the Atomic Energy Commission had carefully developed" with regard to atomic power development in this country.[17]

In view of the dangers in an atomic power plant, as acknowledged by the passage of the Indemnity Act, it is difficult to visualize any "compelling reasons" which could be cited in support of locating a reactor power plant near a populated area. It may be argued that to require the location of an atomic plant in a remote area would result in greater cost of such power to the consumer, and thus postpone the day when atomic power would be economically competitive with thermal or hydro power. However, such an argument lacks merit for three important reasons: (1) It tends to disregard the question of public health and safety; (2) references to atomic power becoming "economically competitive" with electricity produced by conventional means are meaningless because no acceptable basis for comparison of costs between the two methods is available;[18] and (3) it ignores the fact that hydroelectric plants, of necessity, frequently are located at great distances from the service areas.

While it may be argued that the possibilities of an atomic disaster are "believed" to be extremely remote, any effort to claim this as sufficient justification for locating an atomic power plant in the vicinity of a populated region must be regarded as a gross violation of professional engineering responsibilities. To ignore available alternative and knowingly to expose a large population to a hazard of unprecedented magnitude, however remote its occurrence may seem, must be regarded as a gross violation of moral and ethical standards, not only in engineering but also in industry and in government. For a government or its agency to violate such standards and, in addition, to offer incentives which contribute to the violation of such standards, must be regarded as a revolutionary departure from the fundamental principles established by the Constitution of the United States.

VIII. A SILENT REVOLUTION IN OUR FORM OF GOVERNMENT

In this technological age the influence of the scientist and of the engineer (the experts) has assumed tremendous importance in governmental affairs. It may not be remiss at this point to call attention to the relatively simple device by which the highly complex field of science and technology, when dominated by governmental authority, can be applied over a period of years to the introduction of revolutionary changes in our form of government. This is particularly true where we find displacement of independent professional respon-

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17 Petition for a Writ of Certiorari filed by the Government and AEC, No. 454, This Term. p. 11.

18 All of the cost components of conventional power plants are determined through the competitive operations of a free market. On the other hand, many of the comparable costs of atomic power plants are established administratively by governmental authority.

sibilities, or where a commission is so constituted that it regulates its own acts. It is out of such procedures that a new system of "administrative law" is born. Over the years this tends to grow up to form a new legal structure in place of our conventional system of the "rule of law"—and generally beyond the reach of Constitutional controls and our judicial system. We have been warned that eventually such a legal structure can deteriorate into "administrative lawlessness."

The trend towards administrative procedures and law was clearly outlined by the late Lord Chief Justice of England in 1929:[19]

> "Two main obstacles hamper the beneficent work of the expert. One is the Sovereignty of Parliament, and the other is the Rule of Law.
>
> "A kind of fetish-worship, prevalent among an ignorant public, prevents the destruction of these obstacles. The expert, therefore, must make use of the first in order to frustrate the second.
>
> "To this end let him, under Parliamentary forms, clothe himself with despotic power, and then, because the forms are Parliamentary, defy the Law Courts.
>
> "This course will prove tolerably simple if he can: (a) get legislation passed in skeleton form; (b) fill up the gaps with his own rules, orders and regulations; (c) make it difficult or impossible for Parliament to check the said rules, orders and regulations; (d) secure for them the force of statute; (e) make his own decisions final; (f) arrange that the fact of his decision shall be conclusive proof of its legality: (g) take power to modify the provisions of statutes; and (h) prevent and avoid any sort of appeal to a Court of Law."

In the same essay the following warning has been sounded:

> "It is, or at any rate it was until quite recently, a commonplace to say that the 'Rule of Law' is one of the two leading features which distinguish our Constitution. So it has been ever since the eleventh century, and if this leading feature or essential characteristic is to be deminished or destroyed, it seems at least desirable that the work of diminution or demolition should be openly and frankly performed, with the British public standing by, fully instructed and deliberately consenting. Nothing could well be more unfortunate than that a change of so fundamental a character should be brought about piecemeal, by subterranean methods, which might escape general observation until the mischief had been carried to completion."

IX. ISSUES RELEVANT TO THE QUESTIONS BEFORE THE COURT

1. Technology has clearly emerged as a mighty shaper of human destiny. With the development of science and engineering to this dominant role, scientists and engineers have the responsibility of opposing the harmful exploitation of these powerful influences.

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[19] The New Despotism, by Hewart of Bury, Rt. Hon. Lord. Lord Chief Justice of England (dec). (Ernest Benn, Ltd., London), pp. 20, 23.

2. The two areas of responsibility, as between science and engineering must be clearly understood. Scientific truth is naked truth. A scientific principle is a naked principle. Engineering truth is fully clothed in ethics and morality. It is founded on the proposition of individual responsibility. In the application of scientific principles the engineer is expected to serve the public interest with due regard for the preservation of the Rule of Law and our Constitutional system of government. In developing new plans for the future, the engineer interprets the experiences of the past and adds the vital ingredients of imagination, sound judgment and integrity.

3. The atomic age has brought out a major biological factor in our world. The development of atomic power installations has brought with it the problem of radioactive hazards which is becoming an ever increasing danger to human life. In the application of this new science, safety of human beings is the most important consideration. Nuclear radiation not only endangers their immediate health, but also may harm or destroy their offspring.

4. The operation of a large atomic power plant involves many people; a failure in its control can occur at human hands by careless handling, lack of experience, by accident, or by criminal action such as theft or sabotage. Failure can also occur through errors in design of the complex and highly technical apparatus. A general release of radioactive materials, as has already happened, allows them to be spread over the countryside and into the rivers, ultimately reaching man through water and food of all types. "With all the inherent safeguards that can be put into a reactor, there is still no foolproof system. Any system can be defeated by a great enough fool. The real danger occurs when a false sense of security causes a relaxation of caution."[20]

5. The individual scientists and engineers, as well as the leaders in their professional societies have a traditional responsibility of presenting truthful information on both successes and failures in their work and to protest against efforts to misuse their services. Unfortunately the field of atomic power is suffering from lack of interest and concern on the part of most engineers, and from lack of responsible leadership. Furthermore, it is clouded by a variety of professional papers and publications, many of which are misleading or purely propaganda. The lessons of experience in this field are in their embryonic stage and, as the National Academy of Sciences has stated: "Present experiences give us only a shadow of a presentiment of what is yet to come."

6. The atomic power plants which for the most part are being undertaken by private industry at a loss are intended to develop technical knowledge and experience. "There was always a sort of threat, however, that if private industry did not do so the government would build the plants itself. What, if any, influence this had upon private industry's decision it is not possible to say."[21]

7. The threat of government competition to gain political objectives has been the subject of much discussion, as for example:

> "There can be little doubt, when government owns and operates a significant proportion of the capacity to produce electric power, that it gives

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[20] "The Safety of Nuclear Reactors," by C. Rogers McCullough, Chairman of Advisory Committee on Reactor Safeguards, AEC. In 1955 Geneva Conference Proceedings (New York, United Nations, 1956) Vol. 13, p. 79.

[21] "Atomic Energy in a Free Society." Paper presented to Mont Pelerin Society, September 7-12, 1959. In "Il Politico," University of Pavia (Italy), 1960, Vol. XXV, No. 2. p. 296.

to the government a greater ability to dominate and manage other economic activities. Those who favor centralized economic planning (or socialism in the sense of government ownership and operation of the basic industries), are naturally concerned about the role of government in the atomic industry. In the United States, the socialist voice seems to make itself heard by means of the public power advocates in our national legislature, who desire to retain nuclear produced electric power as a national monopoly. If this is possible, not only for electric power but for other aspects of atomic energy as well, the degree of central direction of all economic affairs would be increased and facilitated. . . ."[22]

8. The tendency of technicians to favor centralized planning was examined a few years ago, with great clarity and understanding.[23]

9. It is an ominous spectacle to see governmental authority taking charge of scientific discovery, and undertaking public developments without the benefit of an independent and responsible engineering profession to provide the moderating controls of ethics, morality and justice. This could eventually lead to the destruction of our form of government.

10. History has taught us that when political leaders and administrators in authoritative positions find themselves captivated by the premature application of scientific principles, and choose to take overriding control of them for the purpose of gaining high influence or domination over people and nations, without regard to the hazards or harmful consequences, they are practicing a system of usurpation and immorality in government, and are betraying a public trust.

11. The fundamental issue before this Court is not the simple question whether a specific atomic power plant should or should not have been constructed at a particular site. The basic issues are:

(a) Shall the Government of the United States, by legislation and administrative decision, engage in and foster the application of scientific principles under policies which violate the elementary codes of ethics, morality and justice which have been established by our founding fathers?

(b) Shall the Government of the United States, by the threat of direct competition with its citizens and under its own special rules, place in a defensive position those who are engaged in upholding our system of free and private enterprise under competent State regulatory controls?

(c) Shall the Government of the United States, without the full knowledge and understanding of all its citizens, provide special inducements and incentives for corporations and individuals to engage in the unsound application of scientific principles which contain the hazards of destruction of great numbers of human lives?

(d) What are the responsibilities of scientists and engineers who encourage or condone the enactment of laws for the building of atomic power plants where they will stand as constant threats of disaster to a large number of people at some unexpected time?

12. Whatever may be argued as having been the intent of Congress in the enactment of certain legislation, it must be assumed that Congress expected

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[22] "Atomic Energy in a Free Society," supra, note 21.

[23] "The Counter-Revolution of Science," by F. A. Hayek, Free Press, Glencoe, Illinois. 1952. See esp. Chapter 10, "Engineers and Planners."

the highest standards of professional engineering to be maintained for the health and safety of the public. Furthermore, it is evident that any legislation which creates a conflict with the essentials of professional freedom, or which invites a relaxation of professional standards, can be rectified.

13. It is high time we face up to the hypocrisy of our assumptions, and that we express an angry and solemn warning against varieties of intellectual corruption. We must learn to say "No" to both client and cash when the proposition turns out to be something less than the best. The abandonment of principle for expediency is an advanced symptom of the decay of popular institutions, and the plain fact is that the sickness of an acquisitive society has become so acute we must either redeem it or perish. We must take a moral and principled stand against sacrificing the future of our children and of our children's children and against depriving them of the freedom which is their birthright.

14. Science can provide the answer to many questions but beyond science is God who made both man and science. Man is only beginning to discover science but he is now learning that he can survive on this earth only if he applies science for the benefit of mankind according to the Will of the Creator of all things.

CONCLUSIONS

(1) This Court should find the Atomic Energy Act of 1954 precludes the Atomic Energy Commission from approving a site for an atomic power reactor near a populated area.

(2) The Commission, in granting a permit for the construction of an atomic power reactor, should be required to make adequate findings with respect to the safety of its operation.

(3) The general problems of public policy in the field of atomic power call for re-examination.

(4) Renewed emphasis is needed that our Constitutional form of Government must be respected and defended in the development of modern science.

GENERAL ACKNOWLEDGMENT

In addition to the specific references which have been cited in support of this brief, a comprehensive search has been made in a wide range of publications to gather basic facts in philosophy, engineering and human welfare. The synthesizing of this heritage of the past with the issues of today has, in essence, been a process of engineering design, similar to that employed in designing a bridge. Therefore, a general acknowledgment must be included to all who in the past have sought to show the way toward wisdom and understanding.

Respectfully submitted,

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PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU); and Waterways and Harbors (WW), divisions. Papers sponsored by the Department of Conditions of Practice are identified by the symbols (PP). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper number are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 2703 is identified as 2703(ST1) which indicates that the paper is contained in the first issue of the Journal of the Structural Division during 1961.

VOLUME 86 (1960)

OCTOBER: 2615(EM5), 2616(EM5), 2617(ST10), 2618(SM5), 2619(EM5), 2620(EM5), 2621(ST10), 2622(EM5), 2623(SM5), 2624(EM5), 2625(SM5), 2626(SM5), 2627(EM5), 2628(EM5), 2629(ST10), 2630(ST10), 2631 (PO5)[c], 2632(EM5), 2633(ST10), 2634(ST10), 2635(ST10)[c], 2636(SM5)[c].

NOVEMBER: 2637(ST11), 2638(ST11), 2639(CO3), 2640(ST11), 2641(SA6), 2642(WW4), 2643(ST11), 2644(HY9), 2645(ST11), 2646(HY9), 2647(WW4), 2648(WW4), 2649(WW4), 2650(ST11), 2651(CO3), 2652(HY9), 2653 (HY9), 2654(ST11), 2655(HY9), 2656(HY9), 2657(SA6), 2658(WW4), 2659(WW4)[c], 2660(SA6), 2661(CO3), 2662(CO3), 2663(SA6), 2664(CO3)[c], 2665(HY9)[c], 2666(SA6)[c], 2667(ST11)[c].

DECEMBER: 2668(ST12), 2669(IR4), 2670(SM6), 2671(IR4), 2672(IR4), 2673(IR4), 2674(ST12), 2675(EM6), 2676(IR4), 2677(HW4), 2678(ST12), 2679(EM6), 2680(ST12), 2681(SM6), 2682(IR4), 2683(SM6), 2684(SM6), 2685(IR4), 2686(EM6), 2687(EM6), 2688(EM6), 2689(EM6), 2690(EM6), 2691(EM6)[c], 2692(ST12), 2693 (ST12), 2694(HW4)[c], 2695(IR4)[c], 2696(SM6)[c], 2697(ST12)[c].

VOLUME 87 (1961)

JANUARY: 2698(PP1), 2699(PP1), 2700(HY1), 2701(SA1), 2702(SU1), 2703(ST1), 2704(ST1), 2705(SU1), 2706 (HY1), 2707(HY1), 2708(HY1), 2709(PO1), 2710(HY1), 2711(HY1), 2712(ST1), 2713(HY1), 2714(PO1), 2715 (ST1), 2716(HY1), 2717(SA1), 2718(SA1), 2719(SU1)[c], 2720(SA1)[c], 2721(ST1), 2722(PP1)[c], 2723(PO1)[c], 2724(HY1)[c], 2725(ST1)[c].

FEBRUARY: 2726(WW1), 2727(EM1), 2728(EM1), 2729(WW1), 2730(WW1), 2731(EM1), 2732(SM1), 2733(WW1), 2734(SM1), 2735(EM1), 2736(EM1), 2737(PL1), 2738(PL1), 2739(PL1), 2740(PL1), 2741(EM1), 2742(ST2), 2743(EM1), 2744(WW1), 2745(WW1), 2746(SM1), 2747(WW1), 2748(EM1), 2749(WW1), 2750(WW1)[c], 2751 (EM1)[c], 2752(SM1)[c], 2753(PL1)[c], 2754(ST2)[c], 2755(PL1).

MARCH: 2756(HY2), 2757(IR1), 2758(AT1), 2759(CO1), 2760(HY2), 2761(IR1), 2762(IR1), 2763(HY2), 2764 (ST3), 2765(HY2), 2766(HW1), 2767(SA2), 2768(CO1), 2769(IR1), 2770(HY2), 2771(SA2), 2772(HY2), 2773 (CO1), 2774(AT1), 2775(IR1), 2776(HY2), 2777(HY2), 2778(SA2), 2779(ST3), 2780(HY2), 2781(HY2)[c], 2782 (HW1)[c], 2783(SA2)[c], 2784(CO1), 2785(CO1)[c], 2786(IR1)[c], 2787(ST3)[c], 2788(AT1)[c], 2789(HW1).

APRIL: 2790(EM2), 2791(SM2), 2792(SM2), 2793(SM2), 2794(SM2), 2795(SM2), 2796(SM2), 2797(SM2), 2798 (EM2), 2799(EM2), 2800(EM2), 2801(EM2), 2802(ST4), 2803(EM2)[c], 2804(SM2)[c], 2805(ST4)[c].

MAY: 2806(SA3), 2807(WW2), 2808(HY3), 2809(WW2), 2810(HY3), 2811(WW2), 2812(HY3), 2813(WW2), 2814 (HY3), 2815(WW2), 2816(HY3), 2817(HY3), 2818(SA3), 2819(WW2), 2820(SA3), 2821(WW2), 2822(WW2)[c], 2823(HY3), 2824(SA3), 2825(HY3), 2826(SA3)[c], 2827(HY3)[c].

JUNE: 2828(SM3), 2829(EM3), 2830(EM3), 2831(IR2), 2832(SM3), 2833(HW2), 2834(IR2), 2835(EM3), 2836 (IR2), 2837(IR2), 2838(SM3), 2839(SM3)[c], 2840(IR2)[c], 2841(HW2)[c], 2842(EM3)[c], 2843(ST5), 2844(ST5), 2845(ST5), 2846(ST5)[c].

JULY: 2847(PO2), 2848(SU2), 2849(HY4), 2850(PO2), 2851(HY4), 2852(PO2), 2853(SU2), 2854(HY4), 2855 (PO2), 2856(PO2), 2857(PO2), 2858(SA4), 2859(SU2), 2860(SA4), 2861(PO2), 2862(SA4), 2863(HY4), 2864 (HY4), 2865(HY4), 2866(HY4), 2867(HY4), 2868(PO2)[c], 2869(SA4)[c], 2870(SU2)[c], 2871(HY4), 2872(HY4)[c], 2873(SU2), 2874(SA4).

AUGUST: 2875(WW3), 2876(WW3), 2877(WW3), 2878(SM4), 2879(ST6), 2880(EM4), 2881(SM4), 2882(EM4), 2883(WW3), 2884(EM4), 2885(SM4), 2886(WW3), 2887(EM4), 2888(WW3), 2889(AT2), 2890(AT2), 2891 (AT2), 2892(AT2), 2893(AT2), 2894(AT2), 2895(AT2), 2896(AT2), 2897(AT2), 2898(AT2), 2899(AT2), 2900 (AT2), 2901(AT2), 2902(SM4), 2903(ST6), 2904(ST6), 2905(SM4), 2906(ST6), 2907(EM4), 2908(ST6), 2909 (EM4), 2910(ST6), 2911(EM4), 2912(SM4), 2913(ST6), 2914(WW3)[c], 2915(ST6)[c], 2916(EM4)[c], 2917(SM4)[c].

SEPTEMBER: 2918(SA5)[c], 2919(HW3)[c], 2920(HY5)[c], 2921(SA5), 2922(PL2), 2923(IR3), 2924(HY5), 2925 (HY5), 2926(CP1), 2927(HY5), 2928(IR3), 2929(IR3), 2930(HY5), 2931(CP1), 2932(PL2), 2933(HY5), 2934 (HY5), 2935(HY5), 2936(HY5), 2937(HW3), 2938(CP1), 2939(PL2), 2940(SA5), 2941(SA5), 2942(SA5), 2943 (HY5), 2944(PL2)[c], 2945(CP1)[c], 2946(IR3), 2947(HW3), 2948(IR3), 2949(IR3)[c].

OCTOBER: 2950(PP2), 2951(PP2), 2952(PP2), 2953(ST7), 2954(SM5), 2955(ST7), 2956(ST7), 2957(ST7), 2958 (ST7), 2959(SM5), 2960(EM5), 2961(EM5), 2962(ST7), 2963(ST7), 2964(EM5), 2965(SM5), 2966(SM5), 2967 (ST7), 2968(ST7), 2969(ST7), 2970(ST7), 2971(SM5), 2972(SM5)[c], 2973(EM5)[c], 2974(ST7)[c], 2975(PP2).

c. Discussion of several papers, grouped by divisions.

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BERNHARD DORNBLATT
HENRY W. BUCK
JOHN D. WATSON
HARMER E. DAVIS